AD-A096 289 HAZLETON ENVIRONMENTAL SCIENCES CORP NORTHBROOK IL F/G 8/1
EVALUATION OF PHYSICAL INFORMATION GATHERING METHODS FOR THE UP--ETC(U)
MAY 80 DACW25-79-C-0069
UNCLASSIFIED ES-9060 NL

1 OF 1
AD A
096289

HAZLETON
ENVIRONMENTAL SCIENCES CORPORATION
1500 FRONTAGE ROAD □ NORTHBROOK, ILLINOIS 60062, U.S.A.
PHONE (312) 564-0700 □ TELEX 28-9483 (HAZES NBRK)

II (1)

HAZLETON
ENVIRONMENTAL SCIENCES CORPORATION
1500 FRONTAGE ROAD, NORTHBROOK, ILLINOIS 60062 U.S.A.

REPORT TO

FISH AND WILDLIFE MANAGEMENT WORK GROUP
ROCK ISLAND, ILLINOIS

6 EVALUATION OF PHYSICAL INFORMATION
GATHERING METHODS FOR THE
UPPER MISSISSIPPI RIVER
Stages I and II.

(14) ES-9060

HAZLETON E.S. NO. 9060

PREPARED AND SUBMITTED
BY
HAZLETON ENVIRONMENTAL SCIENCES CORPO~~RATION~~

Report Approved by:

Dr. Larry J. Danek
Director of Oceanography/Limnology

Dr. B. G. Johnson
Vice President and Technical Director

(15) Contract DACW25-79-C-0069
May 1980
(11)

(12) 96

PHONE (312) 564-0700 ▫ TELEX 28 9483 (HAZES NBRK)

411572

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 Introduction

This report presents the results of a literature review investigation to determine the feasibility of and the methodologies for conducting physical inventories in the Upper Mississippi River (UMR). The purpose of the study is to determine if such inventories can be accomplished in a cost effective and time-efficient manner to provide necessary information that can be used to refine and update the existing data base for the GREAT I computerized information system. The physical inventories can then be related to biological inventories and habitat preference information for the purpose of evaluating the possible environmental effects of various management schemes.

The general approach of Hazleton Environmental Sciences (HES) to this study was to first review existing methods in the literature which have been compiled for the GREAT I pilot study area. The objective was to determine which survey techniques and equipment will provide reliable physical data and still be cost effective, time efficient and have applicability to the variety of habitats found in the UMR.

The compromise between accuracy and efficiency was the primary factor in evaluating which methods were most appropriate. The degree of accuracy that was required for each type of measurement was estimated by reviewing the accuracy and types of data that were already in the information system. The information system that is established consists of various information that has been catalogued into 2 1/2 acre grid sections from the entire UMR. Collection of data that are more accurate or more refined than the quality of comparable data already in the system was examined to be sure the additional effort would be cost effective. For example, the collection of submergent information in grid intervals of 1 acre was not considered cost effective when the remainder of the

information in the system was recorded in either 2 1/2 or 10 acre sections. The primary factor, however, for determining which level of effort was most appropriate was through understanding the general objective of the information system which is to provide a broad data base for resource management of the UMR. A secondary objective of the physical inventories is to provide more detailed information on shorter reaches of the river to establish a basis for determining more subtle changes in the river morphology. The more accurate and detailed data will allow for returning to the area in subsequent years and documenting changes. Both of the above objectives were considered when evaluating and recommending methodologies for the physical inventories. Even though, in most cases, a single method or combinations of methods is recommended, all methods that were considered are described for evaluation by the Fish and Wildlife Management Work Group (FWMWG).

This report presents the results of Phase I of the study which is an evaluation and recommendation of methodologies to be used for the physical inventories on the UMR. If the GREAT II FWMWG and the Corps of Engineers (COE) feel that the methods are feasible, authorization will be given to prepare a plan of action for a pilot study to evaluate the selected techniques. The plan of action (Phase II) will address the objectives, methods and materials, scope of work, personnel requirements and other associated costs to conduct the pilot study in a specified area located in Pool 13 of the UMR.

2.0 Literature Survey

Numerous sources were investigated to assess the applicability of various techniques for determining submergent characteristics within a river and to examine existing studies of the UMR to determine to what extent these data may be used to supplement a study on submergent characteristics. The sources investigated included computerized information systems, the GREAT II Annotated Bibliography (HES 1979), other publications not covered in the previous two, in-house consultants and various individuals considered experts in this technical area. We found direct contact with individuals to be the most valuable source of information as most articles did not elaborate on methods used or problems encountered. These experts in various areas (both technical and geographical) were located from the literature and then contacted by phone. The information was relevant, up-to-date and frequently directed us to other valuable sources.

Much of the information collected concerned remote sensing techniques. This was for two reasons: first, many of the techniques for nonremote collection of data are well known and second, for a study of this size, remote sensing (with extensive ground truthing) was considered the one technique that might be very cost effective. Briefly, some of the best information sources will be discussed below.

The publications which provided the best general information on remote sensing techniques included:

1. Remote Sensing of the Environment (Lintz and Simonett 1976)
2. Remote Sensing in Oceanography (American Soc. of Photogrammetry 1973)
3. Upper Mississippi River Habitat Inventory (Hagen et. al. 1977)
4. The Emergent Aquatic Vegetation of Weaver Bottoms (Bilder 1976)
5. Coastal Wetlands: Role of Remote Sensing (Carter 1978)

6. Remote Sensing the White River in Vermont (MacConnell and Niedzwiedz 1979)
7. Upper Mississippi River Underwater Feature Detecting Capabilities of Water Penetrating Aerial Photography. (Caron et al. 1976).

Those individuals contacted that provided the most valuable information on remote sensing techniques included:

1. Merle Meyer, Dept. of Forestry, Univ. of Minnesota, St. Paul, Minnesota
2. John Minor, U.S. Fish and Wildlife Service, St. Paul, Minnesota
3. Virginia Carter, U.S. Geological Survey, Reston, Virginia
4. William MacConnell, Dept. of Forestry and Wildlife Management, Univ. of Massachusetts, Amherst, Massachussetts.
5 John Van Deman, Chicago Aerial Survey, Des Plaines, Illinois

Finally, the government agencies that have large amounts of information on remote sensing techniques or remote sensing data are the following:

1. EROS Data Center, U.S. Geological Survey, Sioux Falls, South Dakota
2. National Environmental Satellite Service, NOAA, Washington, D.C.
3. Remote Sensing Laboratory, Univ. of Minnesota, St. Paul, Minnesota
4. Environmental Research Institute of Michigan, Ann Arbor, Michigan
5. U.S. Soil Conservation Service, Salt Lake City, Utah
6. National Aeronautics and Space Administration, Washington, D.C.
7. U.S. Army Corps of Engineers, various offices
8. U.S. Fish and Wildlife Service, various offices

There were, of course, many more sources than those listed above, but these are considered some of the best and most relevant sources of information on remote sensing. The bibliography located at the end of this report is a list of sources that were examined for information not only on remote sensing, but also the sources for the standard direct sampling techniques investigated as well.

Numerous publications were examined and individuals queried about existing studies in the UMR to ascertain what data may already exist on submergent characteristics. Examined were works either by or for the U.S. Army Corps of Engineers and the U.S. Fish and Wildlife Service and the works of such people as Meyer and Fremling. What became apparent, as expected, was that there exists large amounts of data on wetlands, flood plains, and emergent characteristics, but there is very little up-to-date information on submergent characteristics. This is mainly due to the fact that emphasis thus far has been away from submergent characteristics and many of the remote sensing techniques (such as color infrared) are not particularly applicable to submergent characteristics. Where submergent characteristics data do exist, usually they are 5 or more years old which, for such characteristics as the distribution of submerged aquatic vegetation and bathymetry, means that the data are frequently obsolete. It is also apparent that where information exists it is usually for a small area or section of the river that was collected during a single isolated study, and because of the variety of samplng techniques used, it is difficult to relate the results to other studies on the river. It is HES's intention to develop a data base with the flexibility to add the results of these isolated studies if the data are applicable and valid.

3.0 Evaluation of Methods

3.1 Bathymetry

The depth readings will probably be the most useful of the physical parameters as an aid in resource management of the UMR. By knowing the depth, for example, reasonable estimations of potential fish habitats such as spawning or wintering areas can be made, estimates of water velocity will be possible, and potential areas for aquatic vegetation can be identified. Consequently it is recommended that a disproportionate amount of effort be spent on accurately obtaining bathymetric measurements than is alloted to substrate, velocity and submergent vegetation measurements.

The methods for measuring depth have changed very little in recent years. The two primary methods are still a sounding line or staff and various types of echosounders. A sounding line is simply a weighted line that is marked at various depth intervals. The weight is lowered to the bottom and the depth is read directly from the line. It is recommended that each survey vessel be equipped with a sounding line or staff for taking measurements in shallow water (2 feet or less) and to use as a backup in case the echosounder fails.

The most widely used method of charting water depths is with the use of the fathometer or echosounder. The instrument uses sound waves emitted from a transducer to detect water depth. The two primary manufacturers are Raytheon and Ross Laboratories that produced several grades of equipment that vary in price from about \$300 to \$20,000 and more. The accuracy of measurements vary from a few feet to within a 0.5 ft if properly tuned and calibrated. More details on the operation of fathometers are given in the remote sensing section (Section 3.6).

It is recommended that each survey vessel be equipped with a continuous recording fathometer that will be in continuous operation during all surveys. The water depth will be recorded on strip chart paper and position or other identifying entries can be made directly on the chart paper. The continuous use of the fathometer will allow the operators to locate deep holes or shallow areas even while in transit between stations. It will also allow the operator to quickly determine minimum, maximum, and mean water depth from each 2 1/2 acre grid as the survey vessel passes through the grid section (if such values are desired). The exact type of fathometer that is chosen depends on the exact application desired. A Raytheon Model DE-119 (or equivalent) is recommended for surveys in the main channel and deeper areas. The system records on chart paper and has very precise tuning and calibrating options. It will primarily be used on the 0-50 ft scale where accuracies to within 0.5 ft are possible. It also has the option to change scales if depths greater than 50 ft are encountered. This instrument is a stock item and can be rented for about $20/day. In the backwater areas where water depths are generally less than 10 feet and frequently less than 2 feet, a different fathometer is recommended. A small recording fathometer with either a 0-10 ft or 0-20 ft scale that is capable of recording depths as shallow as 1 ft with an accuracy of at least 0.5 ft would be desirable. The instrument transducer will be placed within the boat and measure water depths directly through the hull which will protect the transducer in shallow areas. Such instruments are not a stock item, but they can be special ordered for about $1000 to $1500 (Raytheon, personal communication 1980). Purchase of 1 or 2 of these instruments should be considered for this survey.

The other possible method of charting the bathymetry is with electromagnetic radiation (EMR) remote sensing techniques. The use of color photographs

may be useful in locating relatively shallow or deep areas or to identify regions that should be more closely surveyed. However, the method can not be used to accurately measure water depth throughout the study area. The potential use of remote sensing for bathymetric surveys is discussed in more detail in Section 3.6.

Regardless of the exact method used it is imperative to adjust the depth readings to a standard reference datum. The suggested reference datum is the flat pool level which for Pool 13 at Dam 13 is 583.0 ft. The water level during the survey will be recorded on each data sheet so that corrections can be made during the data processing stage if required. The pool water level should be obtained at least daily or more frequently if there is a large variation in the stage height during the day. Since during changes in the water level there can be a "tilt" in the pool elevation, it is recommended that the nearest gaging station or an interpolation between gaging stations be used to make the correction for stage height fluctuations. This will allow the data to be comparable throughout the entire pool.

Other possible sources of error that should be mentioned are water level fluctuations caused by wind setup, seiches, barge traffic, and water level differences between the main channel and the backwaters during periods of rapidly rising or falling water levels. In order to correct for these sources of error continuous detailed surveying of the water with precise surveying instruments or establishing a detailed grid of water level gages would be required. Since most of these factors (except barge traffic) generate potential errors of only a few inches and since it would be very expensive to attempt to correct for them, it is recommended that either the possible errors be ignored or the sampling be temporarily postponed. For example, measurements could be

delayed during the passage of a barge if large variations in the water level are noticed or sampling could be postponed for a day or two following a major rainstorm if it seems apparent that the rapidly rising water level may affect the accuracy of the results. It is suggested, however, that under most conditions these variables can be ignored without significantly affecting the quality of the data.

3.2 Water Velocity

There are several methods that can be used to measure water velocity depending on the exact type of application. The method that is applicable in most cases is some type of current meter, either mechanical or electromagnetic. Other methods that can be used for certain applications include: drogues, dye, drifters, mathematical modeling, and, to some degree, remote sensing.

The use of Lagrangian type measurements, which include drogues, dye, and drifters was eliminated from further consideration. These methods are generally used to follow water masses and require considerable time in tracking the motion to compute accurate velocities. The methods will not be efficient and will not provide the resolutions needed to measure velocities in each 2 1/2 acre section of river.

The use of remote sensing (aerial photography) was also considered but discarded as a feasible method. The method can frequently be used to identify general trends in water movement by identifying sediment plumes or temperature variations (infrared), but to obtain the quantitative measurements that are required for this survey the method will not be applicable.

There are several types of current meters that are applicable to this study including various impeller types and several savonius rotor current meters, but the electromagnetic current meters are the most accurate and reli-

able for this type of study. The least expensive current meters are digital flowmeters (e.g. General Oceanics' Model 2030 Digital Flowmeter) that measure the current with an impeller. The impeller rotations are mechanically counted and the velocity is calculated by dividing by the sampling interval and inserting a calibration factor. The threshold speed of the instrument is 0.25 knots and the response of the rotor to current speed is not linear until a speed of 0.75 knots is reached. The poor threshold speed and accuracy and the awkwardness in handling the instrument precludes it from use in this study even though it is very inexpensive.

The several deck readout current meters that were examined included impeller, savonius rotor and electromagnetic type instruments. Almost all of the various types of meters are of sufficient accuracy to be suitable for this type of survey. The price of the instruments are comparable (approximately $2000), but the electromagnetic sensor is more dependable and slightly more accurate. The detection limits on the instruments are about 0.05 knots and the mechanical sensors are accurate to about 3% of full scale. The electromagnetic sensor is slightly better with an accuracy of 2% of full scale. The biggest advantages of the electromagnetic probe are that it is easier to use in the field, less susceptible to damage, no moving parts to foul or wear out, and it has an internal calibration check to assure the instrument is working properly. The instrument is portable as it is smaller than a brief case and runs on regular "D" cell batteries. It is very easy to use and provides an instant readout of water speed. To obtain a measurement the probe is simply lowered into the water as the survey vessel is stopped or held steady against the current and the speed is read directly. This type of instrument is used by the USGS in most of their hydrology studies. All manufacturers produce approximately

the same quality instrument, but the one recommended is a Marsh-McBirney Model 201. The instrument measures only current speed and not direction. The direction can be estimated by noting the orientation of the current vane as the probe descends; for most river studies this is sufficient. If more accurate direction data are required a directional electromagnetic current meter is available (e.g. Marsh-McBirney Model 527). This instrument uses two current sensors to measure the X and Y velocity components and an internal compass to determine the probe orientation. The three readings must then be converted to north and south velocity components or to speed and direction. A Marsh-McBirney Model 201 can be rented for about $15/day; the Model 527 rents for about $40/day.

Mathematical modeling techniques were also considered for estimating water velocities. The most simplistic model considered was to simply divide the river discharge (obtained from USGS gaging stations) by the typical cross sectional area of the river channel to determine the average river speed. This method, however, does not detect speed changes across the channel from shallow to deeper areas which makes it undesirable. A more complex model that computes velocity changes across the river channel was also considered. This model uses the river discharge and the river channel configuration to compute the velocity distribution across the channel. The model, however, is generally limited to a single, well-defined channel to produce reliable results. With the numerous islands, side channels, and broad backwater areas on the Mississippi River, the benefits of the model become very limited and make it less desirable than simply measuring the velocity during the field survey.

Some modeling will be required, however, to adjust the measured velocities to standard, reference conditions. The velocity at a given point in the river will vary considerably depending on the river stage and discharge.

Since the field surveys may extend over several weeks and, consequently, measurements will be made during various river flow conditions, it will be necessary to adjust the readings to correspond to a standard river flow value. The recommended procedure is to use the ratio of the river discharge during the day of sampling with the reference standard (e.g. mean river flow for the area). This ratio will be used to correct the values with the aid of a semiempirical equation developed from the field data. For example, velocity measurements that are made during low flow conditions should be adjusted upward to correspond more closely to values that exist during mean river flow. This will allow for better comparability between stations along the river.

3.3 Substrate

Many fluvial plants and animals that live on or in the substrate prefer only certain types of substrata. Therefore, the substratum of a given stream area indicates the kinds of organisms that can be expected for that area. The character of the substrate considered in conjunction with the water velocity can indicate the relative stability of the submergent habitat.

Numerous sampling and analytical methods for characterizing substrata were examined in the literature. The field sampling methods and equipment included echosounders, corers, dredges, grabs, divers and cameras (Sverdrup et al. 1946, Dietrich 1963, Duxbury 1971, Shepard 1973 and Klemm 1977). The use of echosounders will be discussed in the remote sensing section of this report. The remaining methods will be examined individually and the advantages and disadvantages of each will be discussed.

Corers are frequently used for substrate sampling, but they are used mainly for deep water work. The 3 main types include hand, gravity and piston corers. These, in turn, may be further divided into attached or unattached

(boomerang) corers, explosive corers, vibrator corers, multiple corers, or box corers. Due to the size, weight, power and cost restrictions, all but the small gravity and hand corers may be disregarded (Klemm 1977). Small corers may be deployed with relative ease from a river boat and return with relatively undisturbed samples. However, for sediment sizes greater than or equal to sand ($\geq$ 0.62 mm) the sample is frequently flushed from the corer during retrieval.

Small dredges, while easily deployed, return with a disturbed sample and partial washout of the sample is highly probable (Klemm 1977). Small grabs (e.g. Petite Ponar, small Ekman, etc.) operated by hand should prove to be the best method for substrate sampling. They are inexpensive and relatively lightweight. The Petite Ponar has better penetration than other grabs and screens and side plates reduce washout and shock wave that accompany other grabs (Klemm 1977). A disadvantage with grabs is that the jaws can be blocked with gravel or detritus and the sample washed out.

Observation of the substrate either directly by diver or indirectly by camera is at best qualitative, time consuming and limited by water turbidity. Photographic cameras have the advantage that if the water is clear, a permanent record is made. Television cameras provide real-time information which can be useful in directing further sampling activities. These methods, however, are not recommended for this study because of the water turbidity and the time required to take the photographs and interpret the results.

After examining all of the above field sampling methods for substrate characterization, the use of grabs is considered the best for this type of river study. The analytical methods discussed below will be those that can be applied to grab samples. The analytical methods are divided into rapid qualitative and detailed quantitative analyses. It is recommended that the majority of the

study area be examined rapidly and in a qualitative manner considering the size of the study area and the cost and time requirements for a detailed study.

It is suggested that four parameters (grain size, color, % organics and redox potential) will be determined in a qualitative manner for the substrates. Particle size is indicative of water velocity which allows estimates to be made about the environment. For example, cobbles or gravel would indicate high energy environment, whereas the presence of silt would indicate a more quiescent environment. Size will be determined by observation and for finer sediments by feel. The predominant size will be entered as a code (1-clay, 2-silt, 3-sand, 4-gravel, 5-cobbles and 6-boulders) on a log sheet. Should a second size be discernible, it will be coded in a second column (e.g. a sandy silt would be coded 32).

Color may reflect the color of the source material, the state of oxidation or reduction of the sediment, the amount of organic matter it contains or may simply be related to the fineness of grain (finer materials generally are darker than coarser materials of the same composition). Color charts (e.g. soil color chart, USGS) giving many hues and tints of standard colors with special code names are used for establishing color. This makes it possible for investigators to understand what color, exactly, is being referred to. These codes (or equivalent) will be entered on a log sheet.

The % organics will be entered in either of 2 places. If a grab sample comes up solely with organic matter (possible in the sloughs), a code 7 will be entered in the size column as sediment size ceases to be relevant. If there are obviously some organics mixed in with inorganic sediment, the estimated percentage will be recorded in the organics column. The alternate to visually estimating the organic material is to conduct detailed oxidation analyses in the laboratory.

Finally, using the presence or absence of hydrogen sulfide (H_2S) as an indicator, the environment within the sediment will be classified as reducing or oxidizing. The human nose is sensitive to H_2S and will be used to detect H_2S qualitatively. On the log sheet, the sediment will simply be coded as either reducing or oxidizing. An alternate to simply detecting the presence of H_2S is to use a redox probe. The instrument costs about $1000 and the probe is inserted into the retrieved sediment to measure the reduction-oxidation potential of the sediment.

If more detailed quantitative analyses are required, and also to verify visual observations, representative samples from the grabs should be retained. These samples will be subjected to standard granulometric analysis and the data presented according to Inman (1952). The samples could be used to determine more precise estimates of % organic composition of the sediments, if more detailed measurements are requested. The samples would also be used as reference samples for quality control.

3.4 Submergent Vegetation

Introduction

Aquatic vegetation can be emergent or floating, as well as submergent, and each category is distinctive and very important to the river, backwater and marsh ecosystems which are to be considered in this study. Because it is readily visible, the emergent vegetation may have previously been studied or charted in selected areas of the GREAT II region. However, to provide an adequate characterization of the vegetation community and to account for annual variation and the relationship between the emergent and submergent components of the system, the emergent vegetation must be mapped as part of the present program.

In this section the major hydrobotanical methods will be examined from the standpoint of collection and analysis, and a program will be recommended which can be used to survey the GREAT II region. Literature pertinent to general sampling methods and those which have been applied on the Mississippi River have been reviewed. Rather than incorporate references into the text, most of the formation has been listed in the bibliography portion of this report. The purpose of this approach is to avoid repetitious referencing, especially since the recommended program is a combination of standard techniques which are addressed in most references. Major sources of methods referenced include Forsberg (1959), Phillips (1959), Weber (1973), Meyer (1973), Wood (1975), and Shima et al. (1976). Two Mississippi River Studies, Fremling et al. (1976) and Carpenter (1977) were relied on for selecting the best procedures for the river. Considerations for wetlands classifications are primarily based on Stewart and Kantrud (1971), Cowardin and Johnson (1973), Eisfelder (1975) and Carter et al. (1979).

Most of the techniques discussed below can be applied using either qualitative or quantitative recording methods. Qualitative methods provide estimates of plant density in very general terms, such as abundant, common, present, or rare; in numerical groups, such as 0-10, 10-25, 25-50, 50-100 per unit area; or in percent composition. All of these require a subjective decision on the part of the investigator and therefore cannot be used in statistical comparisons among sites. They are, however, rapid and efficient, thereby allowing characterization of large tracts. Quantitative techniques are more laborious and are only accomplished by identifying and counting all specimens in a unit area. When replicated, the results can be statistically compared to other sites but the time necessary for data collection limits the studies to

relatively small areas. Quantitative sampling is most valuable when specific sites are being studied to evaluate alteration of physical conditions, pollution impact, or other habitat changes.

Logistics of Large-Scale Surveys

Large-scale surveys, such as the one desired for the UMR region, require trade-offs in survey detail. Because it is essential that the field surveys be conducted in a single field year to provide the basis for comparison among the various areas of the region, speed and efficiency of collection are necessary. The time logistics are further complicated by the need to sample the aquatic vegetation during the period of maximum biomass and during the reproductive season. This time is near the end of the growing season, during late summer and early fall, when both vegetative and reproductive structures are present. For these reasons, qualitative surveys, which are much more time efficient than quantitative surveys, are necessary. A combination of preliminary data gathering by aerial photographic techniques (mentioned below), and reliance on visual identification methods, can result in a fairly rapid survey of a large area.

Taxonomy

One of the concessions which becomes necessary in large-scale surveys is a reduction in degree of taxonomic detail. An experienced investigator familiar with the Mississippi River aquatic vegetation could make most identifications in the field. In this respect, identification to genus would present little problem and the major vegetation beds could easily be categorized by dominant and major taxa. This level of identification would also be relatively easy to correlate to the aerial photographs allowing considerable "filling in" of detail in the final mapping process.

The field investigator would also be able to make selected collections for more detailed taxonomic analysis in the laboratory. This would serve two purposes. It would confirm identifications made in the field as well as provide a detailed species list which could be organized on a pool-by-pool or even river mile basis. The advantage of this approach is obvious when consideration of differences among major areas of the river are needed or when review of the presence or absence of rare, endangered or nuisance species is needed.

The list of taxonomic keys, included in the bibliography, has been used in analysis of aquatic plant communities of the Mississippi River and is recommended for making definitive identifications. This list is not all inclusive but will provide an adequate basis for species identification.

Survey Methods

Three basic methods can be used to survey an area. The best study should combine aerial photography, line transect, and quadrat methods, depending on needs of the study. Aerial photography is a valuable tool in studying large tracts because it can be used to determine the presence of aquatic vegetation, to distinguish the size and uniformity of assembages, and to either select areas for further study or identify specific locations which can be examined as typical of an entire area. The best photographic techniques can be summarized as low altitude color, and color infrared imagery, taken both vertically and obliquely. These techniques readily allow for differentiation of emergent, floating, and submergent vegetation and provide a relatively good means of identifying stands of similar composition. Quantification is not possible by this technique other than determination of the total area dominated by a vegetation type. Photographic methods are discussed further in Section 3.6.

Aerial photography must be supplemented by some form of "ground truth" studies to determine the species or species types which make up major assemblages and the degree of similarity between segregated areas. All ground truth methods are either line transect or quadrat methods and may be conducted using either qualitative or quantitative reporting procedures. In the line transect method, transects are established on a map and followed in the field by the investigator with as little deviation as possible. The investigator uses a cruising technique, simply traveling between two readily identified land marks or along a line or tape stretched between two fixed points. This allows pinpoint identification of reference points by a surveyor, if desired. For a qualitative reporting procedure, the investigator records the species and their relative abundance within a certain distance of the transect. For a quantitative reporting procedure, the investigator counts all species which touch or lie within some prescribed distance, such as 1 cm or 1 dm, of the string or tape.

In the quadrat method, the investigator randomly positions unit area frames (usually 1 m^2) within the study area or assemblage type. The number of quadrats sampled is determined by the degree of precision desired. A variation on this method has the investigator placing quadrats along a transect at either regular or random intervals. In a qualitative reporting procedure, the investigator estimates the percent of substrate covered by vegetation and then estimates the abundance of each species in one of the subjective scales described previously. In a quantitative reporting procedure, the investigator identifies and counts all species within the quadrat; sometimes all plants are collected for subsequent counting or for biomass measurements. A modification to this procedure would involve the photographing of the quadrat with an underwater camera and subsequently analyzing the photo in a qualitative or quantitative manner.

Collection Methods

There are a variety of methods available for collecting aquatic vegetation. These may be divided into two types, direct or indirect, depending on whether they are accomplished by the investigator or by some mechanical means. Only some of the more applicable methods will be mentioned.

The visual method involves merely identifying and quantifying vegetation beds while passing nearby in a boat or wading in shallow water areas. In this circumstance the investigator will only occasionally take a portion of, or a whole specimen, for taxonomic corroboration of field identifications. All data are recorded in the field. The depth of water that this technique can be successfully applied is largely dependent upon the turbidity of the water. In some cases, a shadow box may be employed to increase the depth of visibility and better resolve floral components.

Grappling hooks or rakes can be used for the occasional collection of a specific specimen that is out of hand reach of the investigator. They may also be cast at regular intervals, or at random, to provide semi-quantitative estimates of the abundant, common and rare specimens or to provide data on a yield per unit effort basis. These devices may be hauled for uniform short distances with the option of saving each sample for laboratory identification or analysis.

Another technique is the use of dredge or grab samplers which have sufficient power to sample part of the substrate and obtain a known area of sample. This technique is most effective in deeper water and in vegetation which is fairly compact or bottom hugging. Submerged forms of vegetation which develop long stems are resistant to sampling by this technique.

Another effective technique for deeper water is direct observation by divers. A diver can practice the various line transect and quadrat survey techniques mentioned above using qualitative or quantitative methods depending on the need of the study. Collection of voucher specimens is greatly simplified and substrate description and visual identifications in deeper water are more accurate than when made from a boat. Orientation can be difficult, however, and compass courses or anchored lines are usually necessary.

For strictly qualitative evaluations, any effective means of dislodging vegetation from the substrate or fragmenting the plant(s) could be used for collections. Devices or gear such as nets, barbed wire, pumps, etc. could possibly be applied to retrieve specimens for analysis.

Another interesting technique which holds promise for qualitative surveys is the use of recording fathometers. It is known that submersed plants are recorded on fathometer charts but the accuracy and reliability of the instrument is unknown for this particular application. More detailed discussion of the use of fathometers is provided under remote sensing (Section 3.6).

Harvesting must be applied if biomass estimates are to be made or quantification is to be accomplished in the laboratory. Harvesting is done in connection with quadrat surveys where the entire standing crop of vegetation within a quadrat is cut at the substrate surface and placed in bags for return to the laboratory. This method may be practiced along the shoreline, splash zone or in shallow water, or by a diver in deeper water.

Data Reporting

Aquatic vegetation may be described at three levels of complexity; habitus, assemblage or species. In the habitus level, plants are described as emergent, floating or submergent dependent on whether they reach above, lie on,

or are beneath the surface. At times, some care must be exercised to differentiate true floating vegetation from submergent vegetation which may produce near surface or floating leaves and which flower out of the water. These levels of classification are readily made from aerial photographs, as well as, field studies.

Numerous assemblage groupings exist in the literature. These groupings may be described by zones, such as wet-meadow, shallow marsh, deep marsh, etc.; or wetland Types I,II, etc. as used in government schemes. Chemical or physical terms, such as bog, alkali or saline ponds, temporary ponds, etc., may also enter the schemes under certain circumstances. Species assemblage classifications may also be imposed on physical descriptions. These are often based on emergent or floating vegetation types and are particularly effective in near monospecific stands such as cattail marshes, sedges, arrow head or water lilies. With sufficient study detail, major vegetation beds within a region may be classified using localized groupings of the dominant genera with less attention to nationwide schemes. This technique can be especially valuable where historical records are desired since changes in dominant species over time are reflected in the assemblage name.

The greatest detail occurs where the genus or species names of all specimens observed in a particular bed are reported. This technique requires greater detail in taxonomic analysis but is safest when transition zones between major water bodies or habitats such as river channel versus backwater areas occur. This approach is also preferred if the habitat type or species assemblages are suspected to be changing in time or if rare, threatened or endangered species are present.

The cost of the various survey and collection methods is highly variable, dependent upon the degree of detail desired (Table 5, Section 5.0). Quantitative surveys are generally more time consuming than qualitative surveys and, consequently, proportionately more costly. It would not be unrealistic to expend at least four times as many manhours for a quantitative as opposed to a qualitative survey. Quantitative techniques may also require the use of more specialized equipment and personnel which must also be factored into the cost of the program. Probably the least expensive survey method would be the visual, qualitative type made by slowly cruising an area in a boat, estimating percent coverage of the various vegetation types and recording detailed notes on field sheets or site maps. Identifications would be supported by the collection of representative taxa (through hand harvesting, use of a rake or grab sampler, etc.), for subsequent analysis whenever necessary. Hand harvesting of representative specimens or collection with a rake or grappling hook would be preferred over dredges or grab samplers because of ease of use and time efficiency. The former methods would probably require at least 2 minutes per station while the latter would require 4-5 minutes. The least efficient method of sampling would involve direct observations by a diver. This method would be cost prohibitive on a project of the magnitude indicated for the GREAT II Region. The diving effort per station (entering and leaving boat, collecting and bagging samples, etc.) would require a minimum of 20 minutes.

Recommendations

In conclusion, a variety of techniques exist for the study of aquatic vegetation. However, a combination of several of the more general ones are indicated for a large-scale survey such as the one needed for the UMR region. It is recommended that aerial photographs be taken and analyzed to

delineate major vegetation beds and to define areas of apparent similar structure. Qualitative ground truth techniques should then be applied to the areas identified and provisionally mapped using the photographic techniques. Much of the ground truthing may be done by visually characterizing plants along transects with data being recorded in terms of percent substrate coverage and percent composition of the species observed. Large areal extents of vegetation which appear in ground truth studies may be described by qualitative analysis of only two or three quadrats in the entire bed. Vegetation beds should be described using two levels of identification: habitus (emergent, floating and submerged units) and listings of all dominant species observed. The water body type or habitat should also be described in terms of backwater, slough, main channel, etc. with notes of substrate type and water depth being included. Much of this information could be presented in terms of simplified assemblages on scale maps for rapid reference.

While the desired unit for areal resolution is 2 1/2 acres, each unit will not have to be visited by a field team if the above combination of aerial photographic and ground truth methods are applied. The extent of major beds can be predetermined in provisional maps drawn from the photographs so that only selected beds, questionable areas, or transition zones have to be visited and open water or uncolonized areas can be avoided. These techniques will allow attainment of a 0.5 to 1.0 river mile per day schedule for the demonstration survey project planned for the summer of 1980.

Even though the open water period on the river and backwaters extends over approximately a seven month period, aquatic vegetation sampling must be accomplished in a fairly narrow time frame of late summer to early fall. This is necessary to adequately describe the maximum biomass and extent of vegetation

beds and to maximize the collection of flowers or seeds necessary for reliable species identification. To study a large area in this relatively short period, qualitative methods tht will produce definitive field data should be used. Data collected in the manner described above will have a high degree of instantaneous and historical utility while being recorded in small enough areal units for site-specific analysis. The rapidity of the methods will also allow for collection of the data in a single season and therefore maximize comparability throughout the study area.

3.5 Navigation

The precision and accuracy of most field sampling depends on the accuracy and reliability of the method of navigating. Precise navigation methods are available which result in accuracies to within millimeters, but the techniques are comparatively expensive and time consuming. Consequently, it is imperative to determine for each type of field study the tolerances that are acceptable before deciding on the positioning system that will be used. Also each system has its limitations and its general area of applicability that must be considered. The navigation systems or techniques that were investigated for use in conducting the physical inventories on the UMR included: satellite navigation, radar, electronic distance meters, optical range finders, visual estimation from known reference points (including the use of aerial photos), sextants, and Mini-Ranger or Trisponder type navigation systems.

The use of satellite navigation systems is not appropriate for this study. Both the accuracy of the system and the relative cost makes it undesirable. The practical stated accuracy of the systems is about 0.1 nautical miles with an additional error of 0.2 nautical miles per knot error in the estimate of the vessel's ground speed during the time of measurement. The cost

of a unit is about $15,000 to $30,000 depending on the options (estimate for a Magnavox MX1102 Satellite Navigator). The poor accuracy, high price, difficulty of use in a small boat and frequent breaks in data because of satellite attitudes eliminated this type of navigation from further consideration.

The most accurate system considered for the study is an electronic distance meter. This type of instrument uses an infrared or laser beam to measure the distance between the unit and a hand held retroprism reflector with an accuracy of within $\pm$ 15 mm. The units have a range of about 1 mile; however, a new system has been developed that has a range up to 6 miles (Hewlett-Packard Model 3808A). An electronic distance meter can be rented for $50 to $100 a day depending on the total number of rental days, which makes the system relatively economical. The disadvantage of the system is that it requires a shore based operator for the main unit and someone to hold the reflector. Extended surveys will require the shore operator to continually relocate the shore station as the survey progresses along the river. Also the accuracy of the instrument is far greater than required because positioning within a 2 1/2 acre grid is all that is necessary for this survey. This technique will be useful for a more detailed study, but the added field time required to obtain this accuracy will not be beneficial to the overall objective of the survey.

The use of radar navigating during the survey was considered. Although the accuracy would be sufficient, the installation and use of the units on very small survey vessels would be impractical. The possibility of using hand held radar guns was investigated, but no commercially available equipment could be located. The radar units used for traffic control use the Doppler effect to measure speeds and are not designed to measure distance.

Radar transponder type navigation systems were also investigated for applicability for the UMR studies. This type of navigation includes Motorola Mini-Ranger systems and Decca Trisponder systems. The navigation is accomplished with the aid of shore installed transponders that are used to provide range positioning with an accuracy of 3m. The signal has a range of greater than 20 miles, but generally operates on "line-of-sight" so that bluffs or wooded areas would screen the signal. A radio signal is sent from the onboard system, and the elapsed time of the return signal from the transponder is used to compute distance. At least two signals from different shore stations are required to compute the location of the survey vessel. One disadvantage is that the shore stations must be accurately positioned prior to commencement of the survey. Depending on the configuration of the river, several transponders may be required for a particular reach of the river which will require at least one day to position and accurately survey the locations of the transponders. Once the shore stations are positioned, however, the transponders can be used without further attention for 5 to 7 days before the batteries must be replaced. If there are high bluffs where the shore stations can be located or sufficiently clear areas in the study area, a well-established network of shore stations can provide coverage for a 20-mile reach of river. One great advantage of this type of navigation is that once the shore stations are established, the system provides accurate positioning that can be updated as often as every second if desired. The system can be rented for about $200 to $250 a day and is recommended for the detailed intensive survey. This type of navigation, however, is still more accurate then is required to position within each 2 1/2 acre grid and is not recommended for the general survey. This type of navigation system is the one that is used for most hydrographic surveys on rivers, but for this survey the

accuracy is probably not needed and does not justify the expense. It is recommended, however, for large open areas (such as just above Lock & Dam 13) where the shore stations will not require continual relocation.

The type of navigation that is recommended for the general survey of the physical characteristics of the UMR is a combination of visual estimation and reference to local landmarks with the aid of charts, aerial photos, optical range finders and sextants. The primary objective of the navigation is to locate the survey vessel within each 2 1/2 acre grid; consequently, visual navigation will be the fastest and most efficient method and still provide sufficient accuracy. The procedure recommended is to use available aerial photographs, topographic quadrangle maps, GREAT II base maps, COE River Navigation Charts and a preprinted 2 1/2 acre grid system of the study area to locate reference points relative to grid locations. Considerable work has already been completed on the information system by Environmental Systems Research Institute of Redlands, California, and grid systems and base maps (all at the same scale) are already available. A transparency of the grid system will be overlain on an appropriate aerial photograph or other reference map and the distance from grid points to discernible landmarks can easily be scaled from the photo. This will allow the survey team to complete transects of the river very quickly by simply traversing between identifiable landmarks on the photos. The distance that the survey vessel is from identifiable points will be determined with an optical range finder, a sextant, or visual estimation. The optical range finder that is recommended for the study is a Rangematic (price: approximately $100) which is accurate to 1% at 100 yds but decreases to an accuracy of 10% at 1000 yds. The combination of gridded aerial photographs and positioning data relative to identifiable landmarks through the use of range

finders, sextants, compass bearings and visual estimation will provide a quick means for the survey crew to locate the vessel within each 2 1/2 acre sampling area.

In summary, two types of navigating methods are recommended for this study. For the general inventory surveys where massive amounts of data must be collected a visual estimation and location with the aid of aerial photographs is recommended. The recommendations of this method takes into consideration the primary objective of the study which is to inventory submergent characteristics of the UMR to provide a data base for decision making and resources planning on the river. This method sacrifices accuracy but provides a feasible method for potentially surveying over 900 miles of river. For detailed, intensive surveys or large open areas the use of Mini-Ranger systems and/or electronic distance meters are recommended. This will provide the accurate positioning that will be required for detailed surveys of shorter reaches of the river (one to 5 mile sections) that may be conducted to determine subtle changes in the river morphology. The positioning should be tied in with USGS bench marks so that scientists can return to exact locations at any time in the future to document the physical changes in the river channel.

3.6 Remote Sensing

Remote sensing is the acquisition of physical data of an object without contact. The information may be derived from electromagnetic radiation (EMR), magnetic fields, gravitational fields and pressure fluctuations (or sound waves). This section deals with remote sensing using EMR and sound waves as magnetic and gravitational field measurements have different applications. The EMR spectrum, for the purposes of remote sensing ranges from 3×10^{-6} μm wavelengths (γ rays) to 3×10^{6}m (VLF radio waves). A variety of optical scanners, spectrometers and radars are used to record these EMR returns from

the object of interest. Due to poor resolution of satellite imagery only sensors on aircraft will be considered. Remote sensing with sound waves (frequently called echosounding) is done either with a single frequency or multiple frequencies (white noise). These frequencies range from several Hertz (Hz) up to several hundred kiloHertz (KHz).

This section will examine the applicability of the 2 above types of remote sensing to bathymetry, water velocity, substrate, submergent aquatic vegetation (SAV) and navigation. Bathymetry is most frequently determined with some sort of an echosounder. The echosounders predominantly used operate in the KHz range (from 10 to 500 KHz). The choice of frequency is dictated by the nature of the bottom (soft or hard), depth of water and resolution required. Generally the higher frequencies have poor penetration (ideal for soft bottoms), higher attenuation (limiting instrument to shallower water) and high resolution (Ross Labs Technical Bulletins, Raytheon 1974). The lower frequencies enable one to work in much deeper water, but the transmitted signal may pass through any soft surface sediment layer and resolution will be sacrificed. The resolution of any of these instruments is approximately 0.5 ft to 3 ft depending on total water depth and bottom type. Some echosounders today are dual frequency thus obtaining the advantages of both high and low frequencies. These echosounders may be purchased for approximately $10,000.

Bathymetry determinations from various EMR, while still infrequent, are increasing in popularity (Lintz and Simonett 1976, Polcyn 1976 and Caron et al. 1976). These measurements are usually determined using densitometric photographic techniques, multispectral scanners (MSS) or lasers. The densitometric photographic technique can provide bathymetry data to depths of 50 m depending on atmospheric conditions, water clarity, height of platform above

water and frequencies sensed (National Council on Marine Resources and Engineering Development 1967, Ross 1968 and 1969, and Rosenshein et al. 1977). The University of Michigan, with its 18 channel MSS has shown that 12 of the channels cover the region of water transparency (0.4 - 10 μm) and that 0.55 -0.58 μm band provides the greatest penetration. With any multiband technique proper choice of the bands, according to their selectivity of penetration of water, can lead to effective bathymetric mapping (Lintz and Simonett 1976).

Recent experiments with various laser systems operating with a peak power of around 105W indicates that such bathymetry systems are feasible (Hickman et al. 1973 and Lintz and Simonett 1976). The Naval Oceanographic Office has developed a unit PLADS (pulsed light airborne depth sounder); this is a pulsed laser operating at 0.55 μm. It will have a depth accuracy of ± 0.5m, or 5% of measured depth, which ever is greater, and a maximum useful depth range of about 45m (Lintz and Simonett 1976). These specifications are for ideal conditions and the applicability to the UMR is doubtful. A laser can be used to detect depth by measuring the difference between the laser reflection at the surface of the water and the reflection from the bottom. However, the energy attenuation is very rapid in turbid water and the system is generally limited to areas where the bottom is visible (Polcyn 1980, personal communication).

All EMR remote sensing techniques require an expensive platform (usually a small plane), expensive detectors and involved data analysis. In addition extensive ground truthing is required in the form of soundings or echosoundings. Considering these problems and requirements it is recommended that echosounding be used in the EMR for bathymetry studies.

Determining water velocity in a river by remote sensing techniques is limited to the tracking of a marker (e.g. a float or dye) over time. This involves a stationary platform recording the movement of a marker. This technique would be expensive and impractical for the UMR.

Substrate characterization can be done on a gross scale by remote sensing. Using an echosounder, boulders and such features as sand bars, sand waves and wing dams can be detected. Inferences as to substrate type can then be made. The use of EMR remote sensing has been used on the White River in Vermont (MacConnell, personal communication 1979 and MacConnell 1979) to characterize the water and therefore could be used to infer substrate type to a limited degree. MacConnell classified the water as pools (quiescent and deep), exposed stream bed, rills (some exposed boulders producing white water) and riffles (no white water, but boulders just below the surface affect the water). As with bathymetry extensive groundtruthing would be required in the form of grab samples.

Extensive remote sensing work has been done by numerous people on wetland and emergent aquatic vegetation. Much of this work was part of the National Wetlands Inventory. EMR remote sensing has proven quite satisfactory for this type of vegetation. Researchers have used black and white panchromatic film (MacConnell 1979, personal communication) and color and color infrared (CIR) (Bilden 1976, Brown 1978, Carter and Stewart 1975, Gammon et al. 1977, Carter 1978, Gammon and Carter 1979, and Carter et al. 1979). Many researchers worked with a scale of around 1:12,000 on a 9x9 inch format. These photos were often taken in the field and the ground truth data entered directly on the print. If money is available seasonal flights were recommended as certain vegetation reaches maturity at different times and usually mature plants have

more characteristic signatures. One flight should be made between early July and August as most vegetation has reached maturity (Meyer 1979, personal communication and Hagen et al. 1977).

Remote sensing work with SAV's has been done less frequently. The detection of SAV's has long been a problem which is compounded by the tendency of submerged aquatic beds to shift in position and abundance from year to year. The presence of high turbidity limits the effective water penetration of aerial photographs (Carter 1978). With photographic techniques, color film is recommended over CIR or water penetration film. After a study in British Columbia by A.P. Austin and R. Adams, they recommended color and CIR simultaneously at a scale of 1:10,000 or greater. The CIR, while incapable of penetrating water, is good for picking out the emergent portions (e.g. flowers) of the SAV's. This has the added advantage that emergent vegetation can be identified as well. Since the distribution of emergent vegetation is variable with time, it is possible to keep track of its distribution and at the same time emergent and submergent aquatic vegetation associations can be investigated.

Other remote sensing techniques for detecting SAV's include the use of multispectral scanners (MSS) and high resolution echosounders. Wezernak et al. (1974) determined the distribution of Cladophora in Lake Ontario using MSS. This study used a 2 channel model to measure the distribution of Cladophora. This was feasible only because Cladophora was essentially the only aquatic growth present in the nearshore zone. The presence of mixed aquatic communities would have necessitated the use of a more complex multi-channel spectral signature approach (Wezernak et al. 1974). This will be a problem in the UMR where mixed aquatic communities are common and water turbidity is high.

Under favorable conditions it is possible to distinguish between various plant types with a MSS. It is also possible to combine laser sensing with the MSS so that depth can be recorded simultaneously (Polcyn 1980, personal communication). The applicability of the technique, however, is generally limited to the depth of visible detection. Or, as a general rule, it is applicable to 1/2 the depth of Secci disk measurements (Whitlock 1980, personal communication). The best results are obtained at 1/4 the depth of Secci depth measurements. MSS systems do not have the resolution nor the water penetration that can be expected from color and color IR photography. The advantage of MSS is that the data are recorded in digital format and can be entered directly on a computer system. For a pilot study of this type it is recommended that color and color IR be tried first; if that works, then it may be possible to use MSS (Polcyn 1980, personal communication, Whitlock 1980, personal communication). An approximate cost for collecting MSS data for the pilot study area is $21,000. This is the price for obtaining computer compatible tapes and does not include any analysis. The price for the analysis may be comparable depending exactly what resolution and differentiation is required. The system has the potential of being cost effective for collecting water depth and submergent vegetation data on the UMR. It will not be applicable for collecting water velocity and substrate data. Because of the poor resolution and added cost, it is recommended that color and color IR photography be tried first.

The use of high resolution echosounders for detecting SAV's has not been documented, however, the method has been considered potentially feasible (Hay 1979, personal communication and Pollack 1979, personal communication). Both Raytheon and Ross Laboratories produce dual frequency echosounders for approximately $10,000 that could possibly prove useful. The dual frequency is essen-

tial; the low frequency (around 20 kHz) would detect all but the softest bottoms, but pass through the SAV's while the higher frequency (200-400kHz) should be reflected by the SAV's. Depending on the density of the SAV community and the nature of the bottom, one might be able to determine the extent of a SAV community although determination of species composition is highly unlikely.

Extensive ground truthing would be required for all of the above remote sensing techniques. The recommended methods for the UMR are aerial flights with simultaneous recording on color and CIR film at a scale of approximately 1:12,000. These flights would cost approximately $700 per hour. The final product would be a 9x9 inch print which could then have an existing grid system (Environmental Systems Research Institute 1979) overlain on the print. These prints could then be taken out during ground-truthing surveys (concurrent with the bathymetry surveys) and the data coded and placed directly on the print and log sheet. During the bathymetry survey the echosounder could be operated in the dual frequency mode providing supplemental remote sensing data, again backed up with ground truthing.

Finally, the use of aerial photos for navigation purposes is highly recommended and frequently used. An existing grid pattern overlain on the print and with landmarks and visual navigation the vessel can be located.

It is Hazleton Environmental Sciences' recommendation that for a comprehensive study of the UMR, a remote sensing survey be conducted. An EMR remote sensing survey using color and CIR film at a scale of 1:12,000 (1 inch equals 1000 ft) presented in a 9x9 inch format should be made just prior to each ground survey. One flight should be conducted during early July to early August at which time most SAV's have reached maturity. If money permits, 2 or more flights should be made at different times of the year. This would prove useful

in discriminating different species of plants. It is also recommended that every several years, repeat flights be conducted as substantial changes in the UMR have been detected over the past 5 years (Minor 1980, personal communication). The photo produced would be interpreted visually, the interpretations coded and recorded directly on the print. These data would then be used to direct the ground surveys which would supply the necessary detail and gound truth required. Concurrent with the ground surveys, remote sensing by echosounder would be conducted for collecting bathymetry and SAV data. All these data would then be entered by grid square (ESRI 1979) onto the log sheet (Section 4.0) and onto a computer system for further analysis.

4.0 Data Recording Methods

The only two feasible methods of recording the data in field are with the use of a data acquisition system or with field data sheets and manually recording the entries. Data acquisition systems are generally designed for continuous data collection with the use of sensor probes that output an electrical signal that can be digitized and recorded on either paper or magnetic tape. Except for the bathymetry and in some cases the water velocity, the parameters measured during this study can not be recorded directly on magnetic tape for entry into a data base. A system could be designed to allow the data to be entered with a keyboard or thumbwheels and then recorded on tape, but the expense of building such a system and the difficulty in using it in a small boat makes it impractical. The recommended method for recording the data is to simply code the data and enter them on water proof field log sheets. The data can then be key punched and verified directly from the log sheets for about 10-15 cents per station.

The parameters that should be recorded and the recommended format for recording the data for each 2 1/2 acre section are as follows:

Coordinate	Time	Special Codes	Depth	Velocity	Substrate	Vegetation	Water Level	River Discharge
AAAAABBBBB	CCDDEEFF	GHH	IIIJJJKKK	LLLL	MNOOPQ	RSTTUUVV	WWWWXXXX	YYYY

<u>Coordinate</u>: Each grid location will be assigned a rectangular coordinate identification which will correspond with the grid identification for each location that has already been established in the existing data base. This will provide for easy entry of the collected submergent characteristic data into the data base. The "A" value will designate the north component and the "B" value the east component of each section.

Time: The time that each set of measurements was made will be recorded as follows:

C- year
D- month
E- day
F- hour

Special Codes: Two special data codes are recommended. The "G" code will describe how the data were collected, for example:

1- all parameters measured
2- estimated from aerial photographs
3- interpolated
4- only depth measured

The "H" code will allow for special comments to be entered such as:

01- wing dam
02- stump field
03- main channel
04- slough
etc.

Depth: Three fields have been allowed for recording the depth of each section, which will provide space for recording the minimum (I), mean (J) and the maximum (K) depth. It is not recommended that all three parameters be recorded for each 2 1/2 acre section, but it is suggested that space be allowed to record the information if desired. Depth will be recorded in feet to the nearest tenth of a foot.

Velocity: Four digits have been allowed to record the velocity measurements which will be recorded to the nearest tenth of a foot per second. This allows the first digit to be used as a special code. For example, a "+" could be coded to mean water is entering the main channel at this grid point and a "-" could mean water is leaving the main channel and entering a side channel.

Substrate: Five codes are suggested to describe the substrate type. The first two codes will describe the approximate grain size of the sediment as

its primary constituent (M) and its secondary type (N). The classifications that are recommended are:

1. - clay
2. - silt
3. - sand
4. - gravel
5. - cobbles
6. - boulders
7. - organic

It is also suggested that the color (O), the per cent organic matter (P), and the redox potential (Q) of the sediment be recorded.

Vegetation: Five categories have been assigned for describing the vegetation. It is recommended that the per cent cover (R) be estimated and the general vegetation type (S) be recorded which will consist of either submergent, floating or emergent vegetation. The remaining three codes will allow for describing the vegetaton in more detail, if possible, and will include the primary (T),secondary (U) and tertiary (V) constituents of the observed vegetation. The codes for these categories will represent various genera and species that can be entered onto the data sheet. In most cases it is anticipated that identification to the tertiary level will not be done, but providing space adds the flexibility of entering the information if it is available.

Water Level: Water levels during the time of sampling obtained from USGS gaging stations will be recorded for each sampling station. Space has been provided for entering the water level for a downstream (W) and an upstream (X) gaging station. Values will be recorded to the nearest tenth of a foot.

River Discharge: The approximate river discharge (Y) obtained from a USGS gaging station will be recorded to the nearest 100 cubic feet per second.

It is recommended that a data record be filed for each section in the pilot study area that is designated as "water" in the original data base developed

by Environmental Systems Research Institute, even if the data for that section were only estimated or interpolated from other measurements. It is further suggested that only those areas designated as "water" be recorded in order to be consistent with the existing data base. It is also recommended that no hand contouring of the data be done. Once the information is on the computer system it can be computer plotted and contoured if desired. The primary reason for contouring the information on base maps was to prepare it for digitizing and entering into the data base. If the data are digitized and recorded as recommended the intermediate steps of contouring and digitizing can be eliminated.

5.0 Composite Field Survey Techniques

The exact sampling methods and procedures that will be used on the pilot survey will not be determined until the final recommendations are given by the FWMWG. Also the suggested methods will vary because one of the reasons for the pilot study is to test different methods and determine which are most useful and cost effective for measuring the physical characteristics of the UMR. However, in order to give a general idea of how the study is envisioned to proceed and describe how the various sampling methods can be linked into a single, comprehensive survey, a general outline of a possible study design is presented in this section.

The first portion of the study that should be completed is a complete aerial survey in July of the pilot study area to obtain color and color infrared photographs at a scale of 1:12,000. An aerial survey of the area was conducted in 1975, but an updated survey is recommended. The photographs should be examined to identify as many submergent features as possible and to identify areas where ground truthing or areas where more intensive studies should be conducted. A detailed grid system of the study area should be superimposed on the photos and/or navigation charts to aid in navigation and locating the survey vessels within each 2 1/2 acre section. The grid should also be numbered and labeled and data sheets for each point should be prepared on waterproof paper before entering the field. It may even be advisable to plot the proposed ship's track on the charts; although, the exact study design will probably change somewhat as the study progresses and better methods are developed or problems are encountered.

During the actual field study it is recommended that at least 3 survey vessels be available and equipped with continuous recording fathometers for

sampling the variety of habitats that exist in the channels and backwaters of the UMR. One vessel should be equipped for the deeper water including the main channel and major side channels. The remaining two vessels (including an air boat) should be available for sampling the shallower backwaters and sloughs. Since the main channel is usually only a small percentage of the river system, it is recommended that every grid point be covered in this area. Every 2 1/2 acre section should be traversed to determine the minimum, mean and maximum depth, but it is recommended that only every fourth transect be sampled for substrate, water velocity and submergent vegetation. The data for the intermediate three transects can be interpolated from the results of the bordering transects. This, however, should not be an inflexible design as areas of special interest will be identified in the field that will warrant special investigation, but, in general, sampling every fourth transect for substrates, water velocity and submergent vegetation should provide sufficient detail.

The backwaters constitute most of the water surface area as in all of Pool 13 there are 29,103 acres of water surface at flat pool level of which only 7,276 acres are classified as channel waters (U.S. Army Corp of Engineers 1969). Because of the larger area of the backwaters and because of the greater possibility of obtaining useful information from the aerial photographs in the shallower water, it is anticipated that a smaller percentage of grid locations need to be surveyed. However, because of the larger area, it is still estimated that 60 to 70 percent of the field effort should be spent in the backwater areas.

In order to efficiently conduct the survey and make optimum use of the equipment required and to assure that the appropriate level of expertise is

available for each of the disciplines, it is recommended that a crew of approximately 5 scientists and technicians conduct the survey. It is recommended that the studies be conducted from a house boat that will serve both as living quarters and as a field laboratory. The field team leader will operate from the house boat to direct the survey. He will schedule the following day's sampling as well as review the previous day's results to correct any mistakes or note any discrepancies that may arise. He will be available for laboratory analyses that may be required such as keying biological samples. He will also be in radio contact (to the extent possible) with the USGS Gaging Stations to obtain updated water level and river discharge values. The remaining four members of the team will comprise two independent sampling crews that will conduct the field sampling. Depending on how smoothly the sampling progresses it may be necessary to add a sixth member to the crew to act as a general maintenance man to do the cooking, run for supplies and gasoline, repair broken equipment, make arrangements for dockage, etc. The amount of time it will take this crew to complete the sampling in the pilot study area depends greatly on the degree of detail that the FWMWG desires for each location and also on the number of stations that must actually be occupied as opposed to interpolating the results or using the aerial photographs. However, it is estimated that with reasonable success from the aerial photographs and considerable flexibility in interpolating the results in many of the backwater areas, it may be possible to progress at a rate of 0.5 to 1.0 miles per day during good weather conditions and assuming 10- to 12-hour work days.

The total effort for the study depends on the methods that are chosen, the degree of detail that is required and the number of stations that

must be sampled versus those that can be estimated or interpolated. Consequently, as an aid in evaluating the methods, summary tables are provided (Tables 1-6) that present the relative effort that is involved to complete a station for each of the sampling methods considered. These tables will provide the FWMWG with a means for assessing the effort that is involved for each method and determining which methods are feasible and worthy of further consideration. The sampling times per station given in the tables are approximate averages and don't include preparation time; the equipment rental rates and purchase prices are approximate averages. Also the reader should be cautioned that it is difficult to assess the effort of a single component of a large study. For example, eliminating alternate station will not reduce the total field time by 50% as the stations will now be further apart and the transit time between stations will be longer. The tables provided, however, give a general idea of the applicability and the level of effort that is required for each method.

Table 1. Summary Table of the Evaluation of Bathymetric Sampling Methods.

Task and Methods	Cost Effectiveness	Time/ Station	Applicability Throughout the UMR	Accuracy of Output	Comments
Sounding Line	A	1 min	B	A	Good for shallow water
Fathometer[a]	B	<1 min	B	A	Requires water deeper than 2 ft.
Remote Sensing	B	NA	E	D	Poor for deep or turbid water

A = Highly Favorable D = Unfavorable
B = Favorable E = Highly Unfavorable
C = Acceptable NA = Not Applicable

[a] Different fathometers are recommended for deep and shallow water.

Table 2. Summary Table of the Evaluation of Water Velocity Sampling Methods.

Task and Methods	Cost Effectiveness	Time/ Station	Applicability Throughout the UMR	Accuracy of Output	Comments
Dye and Drogues	D	20 min	B	D	Time consuming
Flowmeter	A	5 min	D	E	Poor resolution
Current Meter					
Mechanical	A	1 min	A	B	Good method
Electromagnetic	A	1 min	A	A	Recommended
Modelling	D	NA	D	D	Needed for adjusting data
Remote Sensing	B	NA	D	E	Qualitative only

A = Highly Favorable
B = Favorable
C = Acceptable
D = Unfavorable
E - *Highly Unfavorable*
NA = Not Applicable

Table 3. Summary Table of the Evaluation of Substrate Sampling Methods.

Task and Methods	Cost[a]	Time/ Station	Applicability Throughout the UMR	Accuracy of Output	Comments
Corers	$100 - $1,000	10 min	D	A	Hand corers to piston corers
Dredges	$100	5 min	E	D	Pipe dredge
Grabs	$150 - $300	3 min	A	A	Petite Ponars, Ekmans
Diver	$250/day	5 min	C	B	Observation and occasional sampling
Cameras	$1,000 - $19,000	10 min[c]	D	E	Film reviewed and coded
TV Cameras	$7,500	2 min	D	E	Observation only
Echosounders	$17,600 - $20,000	1 min	D[b]	E	Observation only, dual frequency

A = Highly Favorable D = Unfavorable
B = Favorable E = Highly Unfavorable
C = Acceptable NA = Not Applicable

[a] Prices are for equipment purchase.
[b] Undocumented, would require experimentation.
[c] Includes analysis time.

Table 4. Summary Table of the Evaluation of Substrate Analysis Techniques.

Task and Methods	Cost Effectiveness	Time Efficiency	Applicability Throughout the UMR	Accuracy of Output	Comments
Sediment Size					
Qualitative	B	<1 min	A	C	Observation, texture
Quantitative	E	2.5 hr	C	A	Granulometric analysis
Percent Organics					
Qualitative	B	<1 min	A	D	Observation
Quantitative	D	1 hr	C	A	Oxidation and weight loss
Redox Potential					
Qualitative	A	<1 min	A	C	Odor
Quantitative	C	<1 min	A	A	Redox probe-analyzer
Sediment Color	A	<1 min	A	C	USGS Soil Color Chart

A = Highly Favorable D = Unfavorable
B = Favorable E = Highly Unfavorable
C = Acceptable NA = Not Applicable

Table 5. Summary Table of the Evaluation of Submergent Vegetation Sampling Techniques.

Task and Methods	Cost Effectiveness	Time/ Station	Applicability Throughout the UMR	Accuracy of Output	Comments
Aerial Photography	~$700/Hr[a]	Very Efficient	B	C	Necessary for large-scale qualitative survey
Survey Method[b]					
Qualitative Survey	A				
Line Transect		20 min	C	C	Survey time is dependent
Quadrat		10 min	C	C	upon density of vege:ation
Quantitative	C				
Line Transect		2 hr	D	B	Accuracy of data is overshadowed
Quadrat		1 hr	D	B	by large time expenditure for collection
Collection Method[b]					
Direct					
Visual Observation	A	A	C	C	Observer dependent
Diver Observation	D	D	C	C	Expensive & requires diver training
Hand Harvesting	B	C	C	A	May be logistically difficult
Indirect					
Grappling Hooks/Rakes	B	B	C	C	None
Grabs/Dredges	C	C	C	B	None
Fathometer	B	B	C	C	Technique untested

A = Highly Favorable D = Unfavorable
B = Favorable E = Highly Unfavorable
C = Acceptable NA = Not Applicable

[a] Airplane rental rate
[b] The two survey methods, qualitative and quantitative, may incorporate any of the collection methods; therefore, the categories are not directly comparable.

Table 6. Summary Table of the Evaluation of Navigation Techniques.

Task and Methods	Cost Effectiveness	Time Efficiency[a]	Applicability Throughout the UMR	Accuracy of Output	Comments
Satellite	D	E	C	E	Awkward in small boat
Radar	C	D	E	C	Small units not available
Electronic Distance Meter	C	D	C	A	Requires additional operator
Visual Estimation	A	B	B	C	Acceptable, requires identifiable landmarks
Range Finder	A	B	B	C	1/2 mile range
Mini-Ranger	B	B	B	A	Good for open areas

A = Highly Favorable D = Unfavorable
B = Favorable E = Highly Unfavorable
C = Acceptable NA = Not Applicable

[a] Allow 2 minutes transit time between grid points and an additional 4-5 minutes to anchor depending on depth and currents (anchoring may not be required).

6.0 Stage II: Pilot Study Program

6.1 Introduction

The draft report of the Stage I Study (Methodology and Equipment Review and Evaluation) was submitted to the FWMWG for review. The review comments have subsequently been incorporated into the final report. The review comments included recommendation for equipment to be used and/or tested during the pilot study as well as suggestions for specific sampling techniques that should be used. In addition, the review comments recommended reducing the pilot study area from a 20 mile section of river to four smaller sections that would provide a respresentative sample of the study area. The reduced area would still provide sufficient opportunity to test and evaluate equipment and techniques and also provide sufficient data to develop statistical relationships among the physical parameters.

Subsequent to receipt of the review comments a meeting was held in Rock Island between Hazleton personnel, the Chairman of the FWMWG and the Contracting Officer from the Corps of Engineers, Rock Island District. During this meeting various sampling techniques, priorities, and approaches to a pilot study were discussed further. In addition, a tentative schedule for completing a pilot study to comply with the overall schedule of the FWMWG was developed. Following the meeting a preliminary outline of the proposed pilot study was submitted to the FWMWG. The outline contained a general description of the study including methods, equipment, study locations, analyses, and the approximate costs associated with the study. The outlined approach concentrated on the areas considered to be of highest priority for completing a successful pilot study and developing a reliable data base. The preliminary outline of the pilot study was approved and authorization was given to proceed with the Stage II report.

The following study design was based on the preliminary outline that was submitted and given initial approval. The outline, however, was based on the results of the Stage I Study, review comments from the FWMWG, and subsequent conversations with the Chairman of the FWMWG. The suggested study design incorporates the optimum study period, costs and equipment, and (within the limits of the schedule of the FWMWG) the preferred study duration.

6.2 Goals and Objectives

The goal of the pilot study program is to develop and demonstrate the most cost effective and time efficient method of gathering, manipulating and displaying specific physical information. This information will be used to refine the existing computerized information system. Specific objectives of the pilot study includes investigating methods for measuring, recording and analyzing bathymetric data, water velocity, substrate data, and submergent aquatic vegetation. The data will be recorded as to facilitate comparisons and correlations between measured parameters to determine specific relationships among the variables.

6.3 General Study Plan

The pilot study will be conducted on Pool 13 and part of Pool 14 (Figure 1). The four areas that have been selected are sections between RM 522.0-522.5, RM 526.0-527.0 (Figure 2), RM 541.5-542.5 and RM 544.5-545.5 (Figure 3). These subsections of the pilot study area were selected because they will sufficiently represent various habitats within the pool and tailwaters. They will also provide sufficient opportunity to test and evaluate equipment as well as provide a data base for reliable correlation of the physical parameters. The reduction of the size of the study area will also reduce the level of effort required to complete the pilot study, but still provides sufficient information to meet the objectives of the program.

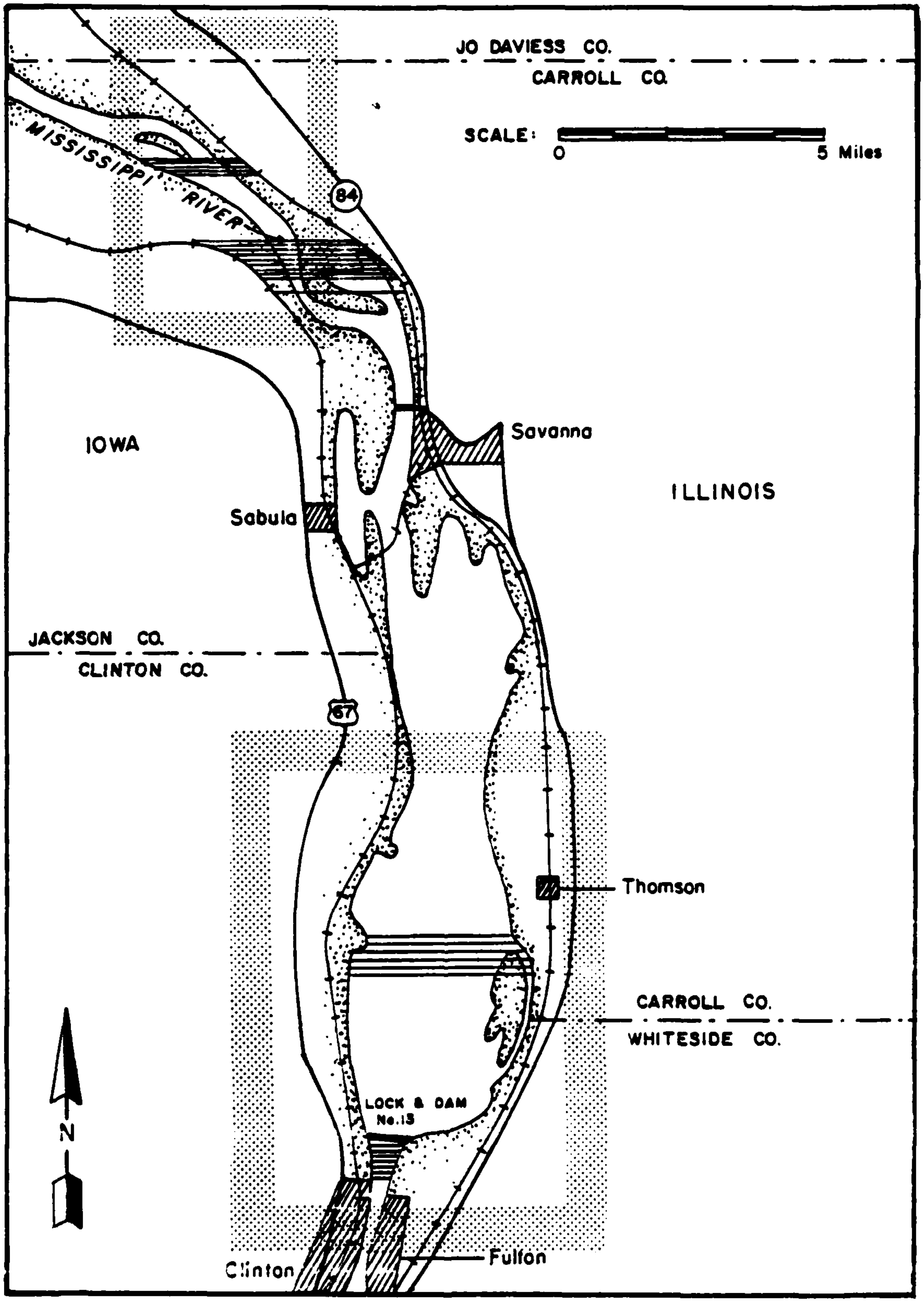

Figure 1. Pilot study area in Pools 13 and 14 showing sampling areas.

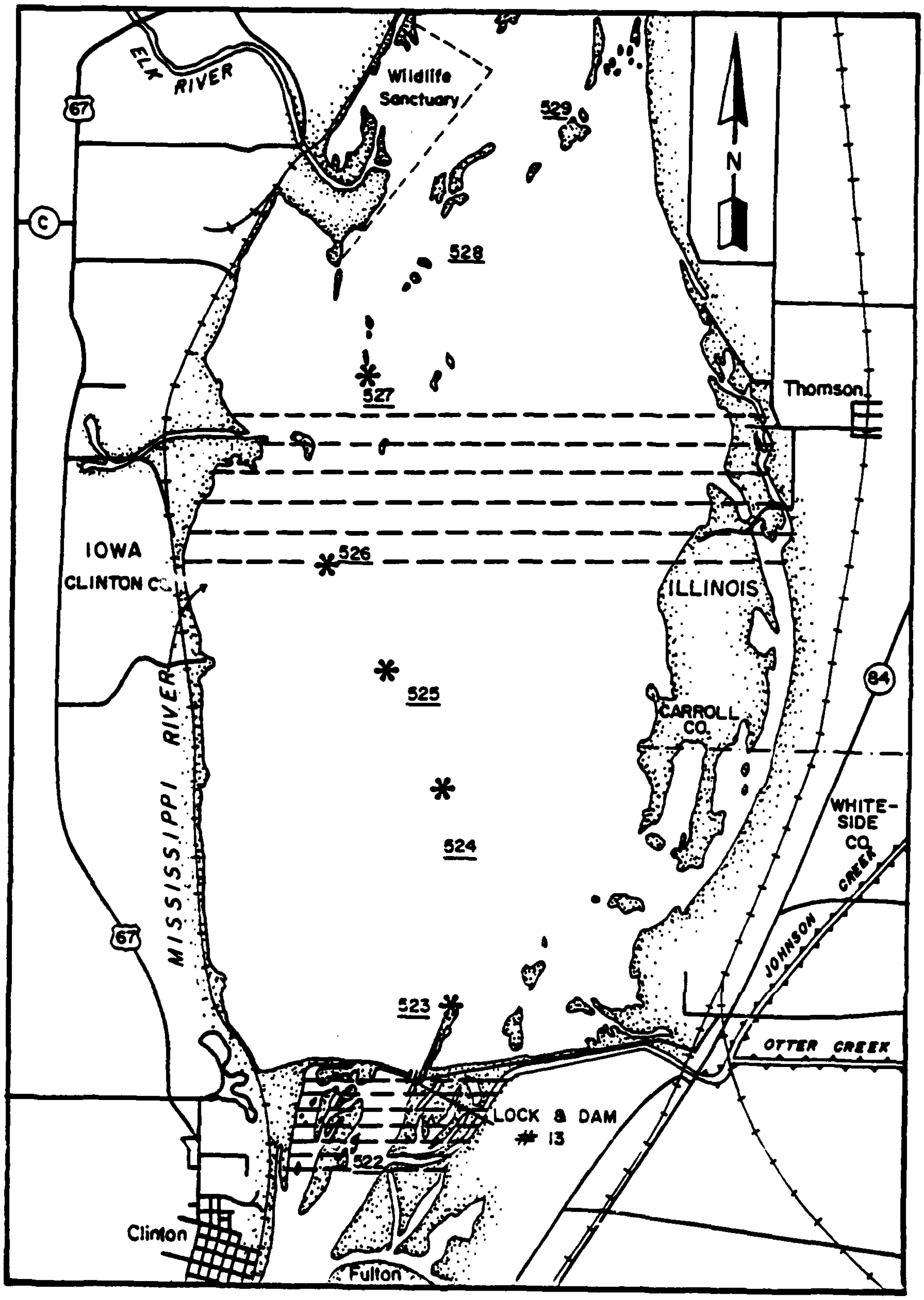

Figure 2. Two of the four sampling areas showing the approximate location of sampling transects.

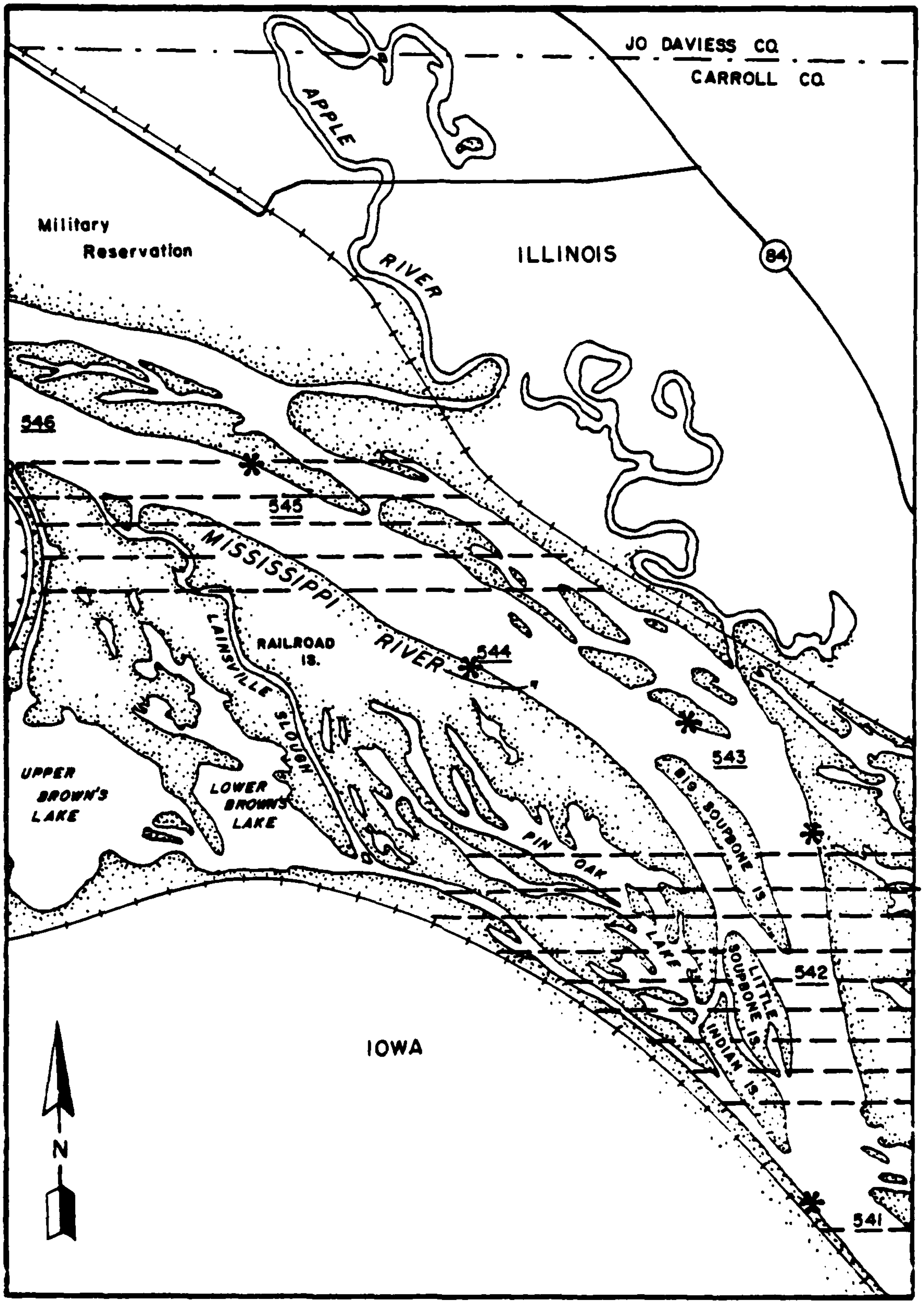

Figure 3. Two of the sampling areas showing the approximate location of the sampling transects.

Within each area 2-1/2 acre grid locations will be sampled for depth, water velocity, substrate, and submergent vegetation. Approximately 1/2 of the available grid locations in each area will be sampied except at RM 526.0-527.0 where approximately 1/3 of the stations will be sampled because of the relatively larger surface area in this section. Samples will be taken along alternate transects in the more open areas. In the slough and side channel areas less attention will be given to following specific transects because of the irregular configurations of the sloughs and tailwater areas. However, about 1/2 of the available grid locations will be sampled in these areas. The sampling methods that will be used or tested for each parameter are given in Section 6.4.

During the period of the field sampling effort (which should last about 10 days) a remote sensing survey of the entire pilot study area will be conducted (between RM 522 and RM 546). Color and color infrared photos of the study area will be made at a scale of about 1:12,000. In addition to the color photos a total of approximately eight black and white enlargements will be made of the four study areas to provide greater detail in the areas where field sampling is being conducted.

Following the field sampling, and after preliminary examinations of the aerial photos a two-day field sampling trip for a single crew will be scheduled. The field survey will be used to further investigate any particular areas or to verify any interesting images apparent on the photos. The final survey will also provide an additional opportunity to test or verify any sampling equipment or variation of methods that may prove to be promising during the main survey.

The data collected during the field survey will be edited, verified and entered onto a computer system in a format compatible to the information system developed for the UMR. Because of the scheduling deadlines, approximately

2-3 weeks will be available for data analysis. The physical parameters will be correlated and regression equations will be developed to describe the relationships between the major parameters. Statistical distributions (such as percent distribution of substrate type versus velocity) and distribution plots will be developed to illustrate the results. In addition, the aerial photos will be examined and interpreted and the results will be compared with the field data to evaluate the applicability of remote sensing to a submergent characteristics study on the UMR.

A draft final report will be submitted to the FWMWG. The report will concentrate on evaluating the techniques used and the feasibility of expanding the study to the entire UMR. The report will also present the data collected and illustrate the relationships found among the physical parameters. Following receipt of review comments from the FWMWG a final report will be submitted.

A more detailed description of the methods and equipment that will be used and the results that are expected from the study is presented below.

6.4 Methods and Equipment

The first task of the study will be to mobilize for the field survey. This will include preparing boats and obtaining, calibrating, or adapting equipment for the survey. Final scheduling and coordination will be completed with the FMWMG, Rock Island COE, and the COE Lock and Dam personnel for controlling water levels during the survey. Arrangements for subcontracting the aerial photography will be completed and final choices of film types and filters will be made. The navigation charts will be completed by merging 1975 aerial photos for each area (provided by the Rock Island COE) with a scaled grid pattern that outlines each sampling location. In addition, the final field data sheets will be prepared. The data sheets will be based on the

format presented in Section 4.0 and will be approved by the Chairman of the FMWMG before they are finalized and field sampling begins.

The primary field sampling team will consist of two 3-man crews. Sampling will correspond to ESRI's grid system with approximately 50% of available grid locations being sampled as outlined above. The methods that will be used or tested during the survey are as follows:

Water Velocity. Water velocity will be measured at each sampling station with an electromagnetic current meter and recorded on log sheets to the nearest 0.1 fps.

Bathymetry. Depth will be measured with continuous recording fathometers in the deeper areas (greater than 3 ft) and with sounding lines and staffs in shallower areas. As a minimum the mean depth will be recorded, but, whenever possible, the minimum and maximum depth measured by the fathometer while traversing a grid section will be recorded. The depth will be recorded to the nearest 0.5 ft. No contour plots will be made as the data will be digitized and entered directly onto a computer. Plots can be generated at a later date if desired.

Substrate. Substrate will be sampled at each station with Ponar and petite Ponar grabs. The Ponar grabs will be lowered from a boom and winch installed on each survey vessel; the petite Ponar grabs will be lowered by hand. The system that proves most efficient will be used for most of the study. Visual estimations will be made of the sediments for grain size, color, percent organics, and redox potential. In addition, the dual frequency fathometer will be tested to determine its applicability in identifying substrate type.

Submergent vegetation. Submergent vegetation will be identified in the field through visual observation with verification from grab samples and SAV

rakes as required. The data will be recorded on log sheets according to the format outlined in Section 4.0. Aerial photography and a dual frequency fathometer will also be used to identify and chart submergent vegetation.

Aerial photography

Color and color infrared aerial photographs of a 24-mile section of the study area will be made. In addition, approximately eight black and white enlargements of the field survey areas will be made to provide greater detail in these locations. These photos will be examined to locate macrophyte beds, bathymetry variations and other information that will be applicable to the study. The photos will also be compared with the results of the field survey. The enlargments will be compared with the photos taken in 1975 to identify changes that have taken place in the past 5 years. This comparison will help determine the applicability and length of time such measurements are valid. Supplemental information such as Secci disk measurements, turbidity, dissolved organic carbon, etc. will be made in the field while the aerial photographs are taken to document the conditions during the aerial survey.

Navigation

Navigation will be accomplished with grid overlays on aerial photographs and GREAT basemaps with the aid of rangefinders and visual estimation. MiniRanger navigation will be used in the study area between RM 526 and RM 527 which is a large open area where rangefinders can not be used.

6.5 Expected Results

The results of the pilot study will include a complete evaluation of the methods and equipment used or tested during the field survey. The experience and data gained from the pilot study will be used to discuss the feasibility and applicability of extending the survey throughout the UMR. A

recommendation as to the most cost effective method of sampling the entire UMR will be provided. The recommendations will include an estimate of time requirements and costs for completing the survey.

The results will also include submission of a comprehensive data base with all the physical parameters correlated according to grid locations. The data base will contain the information outlined in Section 4.0 for each grid location sampled. The data will be statistically correlated to determine the relationship between some of the major physical parameters. Several frequency distribution plots will also be presented to illustrate certain aspects of relationships between the parameters. The data base will be developed such that habitat curves can be constructed from the data at a later time if required.

Because of dividing the pilot study area into four subsections and because of only sampling alternate transects, the data will not be mapped on base maps for display. The efforts of the study will be concentrated on evaluating the equipment and developing a reliable data base. Subsequent to development of the data base the result can be computer or hand plotted if desired, but this task will not be performed for this study.

6.6 Personnel Requirements, Costs and Schedule

A tentative schedule for the conduct and completion of the pilot study and the reporting is given in Table 7. The personnel and equipment requirements and the associated costs for conducting the pilot study are provided as an attachment.

Table 7. Tentative Schedule for the Pilot Study

Date	Action
May 22	Submission of draft report for Stages I and II which will include a firm price for completing Stages III and IV.
June 9	Formal contract modification received from the Government.
June 10	Begin mobilizing for the pilot study. Attend scheduling meeting with the FWMWG.
July 7	Begin the field portion of the pilot study.
July 15	Complete aerial photography.
July 22	Complete the field portion of the pilot study.
July 29	Attend coordination meeting with the FWMWG.
September 2	Draft report for the pilot study submitted.
September 15	Comments on draft report received from FWMWG. Attend workshop to discuss review comments.
September 30	Final report submitted.

7.0 Bibliography

Andersen, M. L. 1976. Causes of decreased migrant waterfowl use in part of the Upper Mississippi River Wildlife and Fish Refuge. Unpubl. master's thesis, Univ. of Wisconsin, Stevens Point. 63 pp.

Anderson, H. G. 1959. Food habits of migratory ducks in Illinois. Ill. Nat. Hist. Surv. Bull. Vol. 27, Art. 4. 55 pp.

Anderson, W. H. and F. X. Wallner. 1978. Small format aerial photography: a selected bibliography. U.S. Dept. Interior, Geological Survey. Sioux Falls, South Dakota.

Austin, A. and R. Adams. 1978. Aerial color infrared survey of marine plant resources. In: Photogrammetric Engineering and Remote Sensing, Vol. 44, No. 4. April 1978. pp. 469-480.

Bade, J. 1979. Personal communication. U.S. Fish and Wildlife Service. Rock Island, Illinois.

Baumann, P. C., J. F. Kitchell, J. J. Magnuson, and T. B. Kayes. 1974. Lake Wingra, 1837-1973: A case history of human impact. Paper No. 86, Univ. Wis. Arboretum, Univ. Wis. pp. 57-94.

Benton, A. R., Jr. and R. M. Newman. 1976. Color aerial photography for aquatic plant monitoring. In: Journalfor Aquatic Plant Management, Vol. 14, June 1976. pp. 14-16.

Benton, A. R., Jr., W. W. Snell, and C. Clark. 1978. Seasonal aerial photographic mapping of Galveston Island. In: Coastal Zone 78 Symposium on Technical, Environmental, Socioeconomic and Regulatory Aspects of Coastal Zone Management. San Francisco, March 14-16, 1978. V. II pp. 1205-1222. ASCE, New York, N.Y.

Bilder, J. M. 1976. The emergent aquatic vegetation of Weaver Bottoms. Unpubl. bachelor's thesis, Environmental Studies Center, St. Mary's College, Winona, Minn. 33 pp.

Born, S. M. 1974. Inland lake demonstration project (May 1968-March 1974). Environmental Resources Unit, Univ. Wis. Extension, Madison, Wis. 31 pp.

Brown, W. 1978. Wetland mapping in New Jersey and New York. Photogrammetric Engr. and Remote Sensing. Vol. 44, No. 3. March 1978. pp. 303-314.

Butera, M. K. 1976. A technique development for the determination of Louisiana marsh salinity zones from vegetation mapped by multispectral scanner data, a comparison of results from satellite and aircraft data. NASA Earth Resources Laboratory Report No. 161. Lyndon B. Johnson Space Center. Houston, Texas. 54 pp.

Cameron, H. L. 1950. The use of aerial photography in seaweed surveys. Photogramm. Eng. V. 16, No. 4. pp. 493-501.

Caron, L., J. Minor, and M. Meyer. 1976. Upper Mississippi River underwater feature detection capabilities of water penetrating aerial photography. Remote sensing applications in agriculture and forestry. IAFHE RSL Research Report 76-1, Minn. Univ. Inst. of Agri., For. and Home Economics. College of Forestry and the Agricultural Exp. Sta., Remote Sensing Lab. St. Paul, MN. 15 pp.

Carpenter, G. F. 1977. Macrophytes. In: Operational environmental monitoring in the Mississippi River near Quad-Cities Station. Report to Commonwealth Edison Co. by NALCO Environmental Sciences.

Carter, V. 1978. Coastal wetlands: role of remote sensing. In: Coastal Zone 78 Symposium on Technical, Environmental, Socioeconomic and Regulatory Aspects of Coastal Zone Management. San Francisco, March 14-16, 1978. V. II pp. 1261-1283. ASCE, New York, N.Y.

Carter, V. 1979. Personal communication. U.S. Geological Survey. Reston, Virginia.

Carter, V., D. L. Malone, and J. H. Burbank. 1979. Wetland classification and mapping in western Tennessee. Photogrammetric Engr. and Remote Sensing. Vol. 45, No. 3. March 1979. pp. 273-284.

Carter, V. and W. R. Stewart. 1975. Seasonal color-infrared photographs for mapping inland wetlands on U.S. Geological Survey 7.5-minute quadrangles. In: The 5th Biennial Workshop on Color Aerial Photography in the Plant Sciences and Related Fields. August 19-21, 1975. EROS Data Center. Sioux Falls, SD. pp. 143-161.

Churchill, M. S. and T. A. Wojtalik. 1969. Effects of heated discharges: The T.V.A. experience. Nuclear News (September). pp. 80-86.

Cihlar, J. 1978. CCRS airborne program assessment: Volume 1 - Analysis. Canada Centre for Remote Sensing. Dept. Energy, Mines and Resources. Ottawa.

Civco, D. L., W. C. Kennard, M. W. Lefor. 1978. A technique for evaluating inland wetland photointerpretation: the cell analytical method (CAM). Photogrammetric Engr. and Remote Sensing. Vol. 44, No. 8. August 1978. pp. 1045-1052.

Clapp, J. L. 1972. Application of remote sensing to water resources problems. In: Fourth Annual Earth Resources Program Review. 17-21 January 1972. NASA Manned Spacecraft Center, Houston. 2(46):1-39.

Cowardin, L. M. and D. M. Johnson. 1973. A preliminary classification of wetland plant communities in north-central Minnesota. U.S.D.I., Fish and Wildlife Service. Special Scientific Report-Wildlife No. 168: 33 pp.

Degenhardt, E. A. ____. Application of color infrared photography to the Mississippi River. Pap. pres. 26th Ann. Potom. Conf., U.S. Army Corps of Eng. LMVD, Vicksburg. 12 pp.

Dietrich, G. 1963. General oceanography, an introduction. John Wiley and Sons, New York. 588 pp.

Duxbury, A. C. 1971. The earth and its oceans. Addison-Wesley Pub. Co., Reading, Mass. 381 pp.

Edmondson, W.T. (ed.). 1959. Freshwater biology. 2nd ed. John Wiley & Sons, Inc. New York. 1248. pp.

Edwards, R. W. and M. Owens. 1960. The effects of plants on river conditions. I. Summer crops and estimates of net productivity of macrophytes in a chalk stream. J. Ecol. 48:151-160.

Eisfelder, C. H. 1975. Wetlands preservation through inventory, regulation, acquisition, and management, wetlands project. Proceedings of the Lake Management Conference. Water Resources Research Center, Purdue Univ., West Lafayette, Ind. pp. 148-150.

Fassett, N. C. 1957. A manual of aquatic plants. Univ. Wisconsin Press, Madison, Wis. 405 pp.

Forsberg, C. 1959. Quantitative sampling of subaquatic vegetation. Oikos, 10:233-240.

Fortunatov, M. V. 1957. Aerial methods and their application in limnological study in inland water bodies. In: Transactions of the Sixth Conference on the Biology of Inland Waters. Edited by E. N. Pavlovskii. Original in Russian. Israel Program for Scientific Translation. Jerusalem: LPST Press. 1969. pp. 591-601.

Fremling, C. R., D. R. McConville, D. N. Nielsen, and R. N. Vose. 1976. The Weaver Bottoms: A field model for the rehabilitation of backwater areas of the Upper Mississippi River by modification of standard channel maintenance practices. Prepared for the U.S. Army Corps of Engineers, St. Paul District, St. Paul, Minnesota. Contract No. DACW37-75-C-0193.

Fremling, C. R., D. N. Nielsen, D. R. McConville, R. N. Vose, and R. A. Faber. 1979. The feasibility and environmental effects of opening side channels in five areas of the Mississippi River (West Newton Chute, Fountain City Bay, Sam Gordy Slough, Kruger Slough and Island 42). Prepared for the U.S. Fish and Wildlife Service, Twin Cities, Minnesota. Contract No. 14-16-0008-949.

Gammon, P. T., and V. Carter. 1979. Vegetation mapping with seasonal color infrared photographs. Photogrammetric Engr. and Remote Sensing. Vol. 45, No. 1. January 1979. pp. 87-97.

Gammon, P. T., D. Malone, P. D. Brooks, and V. Carter. 1977. Three approaches to the classification and mapping of inland waters. In: Proceedings. of the 11th International Symposium on Remote Sencing of Environment. 25-29 April 1977.

Garrett, M. K. and V. Carter. 1977. Contribution of remote sensing to habitat evaluation and management in a highly altered ecosystem. In: Transactions of the 42nd North American Wildlife and Natural Resources Conference, 1977. Wildlife Management Institute. Washington, D.C. pp. 56-65.

Gates, D. M. ____. Characteristics of soil and vegetated surfaces to reflected and emitted radiation.

Gleason, H. A. and A. Cronquist. 1963. Manual of vascular plants of northeastern United States and Canada. D. Van Nostrand Co., Inc., Princeton, N.J. 810 pp.

Green, W. E. 1947. Distribution of marsh and aquatic plants on the Upper Mississippi River Wildlife Refuge. U.S.D.I., Bur. Sport Fish. and Wildl. Winona, Minn. 132 pp.

__________. 1960. Ecological changes on the Upper Mississippi Wildlife and Fish Refuge since inception of the 9-foot channel. U.S.D.I., Bur. Sport Fish. and Wildl. Winona, Minn. 15 p. mimeo.

Greentree, W.J. and R. C. Aldrich. 1976. Evaluating stream trout habitat on large-scale aerial color photographs. USDA Forest Service Research Paper R5 W-123. 21 pp.

Hagen, R., L. Werth, and M. Meyer. 1977. Upper Mississippi River habitat inventory. Final (Narrative) Report-Phase 1 subproject titled "High Stage 1:24,000 CIR Mississippi River Cover Type Mapping - Guttenberg, IA to Cairo, IL" sponsored by the USDI - Fish and Wildlife Service (Contract No. 14-16-0003-30, 686). Remote Sensing Laboratory of the College of Forestry and the Agricultural Experiment Station, Univ. of Minnesota, St. Paul. Minnesota.

Hasell, P. G., Jr., et al. 1974. Michigan experimental multispectral mapping system - a description of the MF Airborne Sensor and its performance. Environmental Research Institute of Michigan. Ann Arbor, Michigan. Report 190900-10-T. January, 1974. 148 pp.

Hay, A. 1979. Personal communication. Institute of Oceanography, Univ. of British Columbia. Victoria, Canada.

Hickman, G. D., E. J. Friedman, C. S. Gault, A. H. Ghovanlou, and J. E. Hogg. 1973. Recent progress in the hydrographic applications of a N_2/Ne laser. In: Proceedings of the American Society of Photogrammetry, October 2-5, 1973, Lake Buena Vista, Florida. Part II.

Hilland, J. E. 1979. Personal communication. National Marine Fisheries Laboratory, Northeast Fisheries Center. Narragansett, Rhode Island.

Hotchkiss, N. 1972. Common marsh underwater and floating-leaved plants of the United States and Canada. Dover Pub., Inc., New York. 223 pp.

Hutchinson, G. E. 1975. A treatise on limnology: Vol. 3, Limnological Botany. John Wiley and Sons, N.Y. 660 pp.

Hynes, H. B. N. 1970. The ecology of running waters. Univ. Toronto Press, Toronto. 555 pp.

Kelly, M. G. and A. Conrod. 1969. Aerial photographic studies of shallow water benthic ecology. In: Remote Sensing in Ecology. Athens: University of Georgia Press. pp. 173-184.

Keown, M. P., E. A. Dardeau, and J. G. Kennedy. 1977. Inventory of sediment sample collection stations in the Mississippi River Basin. Army Engineer Waterways Experiment Station. Vicksburg, Miss. 498 pp.

Kiefer, R. W. and J. P. Scherz. 1971. Aerial photography for water resources studies. Journal Surveying Mapping Division. Proceedings American Society Civil Engineers. SU2(8545): 321-333.

Kitchell, J. F. 1975. Lake Wingra, Wisconsin: A case history of good intentions. Proceedings of the Lake Management Conference. Water Resources Research Center, Purdue Univ., West Lafayette, Ind. pp. 49-56.

Klemm, D. J. (Chairman). 1977. Biological field methods: a working document of ASTM D-19 Subcommittee 23 (macroinvertebrates). Unpubl.

Knight, R. R. 1965. Vegetation characteristics and waterfowl usage of a Montana water area. J. Wildl. Mgt. 29:782-788.

Kolipinski, M. C. and A. L. Higer. 1968. Applications of aerial photography and remote sensing to hydrobiological research in south Florida. Open File Report. U.S. Geological Survey. Water Resources Division. Miami, Florida. 7 pp.

Krull, J. N. 1970. Aquatic plant-macroinvertebrate associations and waterfowl. J. Wildl. Mgt. 34:707-718.

Lintz, J., Jr. and D. S. Simonett. 1976. Remote sensing in the environment. Addison-Wesley Pub. Co., Reading, Mass. 694 pp.

Limpert, R. and R. Vose. 1976. Fall feeding habits of migrating whistling swans on the Upper Mississippi River. Submitted to J. Wildl. Mgt. January, 1976.

Lukens, J. E. 1968. Color aerial photography for aquatic vegetation surveys. Proc. 5th Symp., Remote Sensing of Environment. Univ. of Michigan, Ann Arbor. pp. 441-446.

MacConnell, W. P. and W. Archey. 1969. The use of aerial photographs to evaluate the recreational resources of the Connecticut River in New Hampshire. Massachusetts Agri. Exp. Sta. Bulletin No. 576. University of Massachusetts, Amherst. 81 pp.

MacConnell, W. P. 1975. Remote sensing 20 years of change in Massachusetts. Massachusetts Agri. Exp. Sta. Bulletin No. 630. University of Massachusetts, Amherst. 79 pp.

MacConnell, W. P. 1979. Personal communication. Dept. Forestry and Wildlife Management, Univ. of Massachusetts. Amherst, Massachusetts.

MacConnell, W. P. and W. Niedzwiedz. 1979. Remote sensing the White River in Vermont. Photogrammetric Engineering and Remote Sensing. V. 45, No. 10. October 1979. pp. 1393-1399.

MacKenthun, K. M. and W. M. Ingram. 1967. Biologically associated problems in freshwater environments, their identification and control. U.S.D.I., Federal Water Pollution Control Administration. 287 pp.

Macomber, R. T. 1978. Aerial photography and seaplane reconnaissance to produce the first distribution inventory of submerged aquatic vegetation in Chesapeake Bay, Maryland. Unpubl. paper. Earth Satellite Corporation. Washington, D. C. 6 pp.

Masry, S. E. and S. MacRitchie. 1980. Different considerations in coastal mapping. In: Photogrammetric Engineering and Remote Sensing. Vol. 46, No. 4. April 1980. pp. 521-528.

Martin, A. C. and F. M. Uhler. 1939. Food of game ducks in the United States and Canada. U.S. Dept. Agric. Tech. Bull. 634. March. 156 pp.

Meyer, M. P. 1973. Remote sensing applications in agriculture and forestry: operating manual-Montana 35 mm aerial photography system (1st revision). Remote Sensing Laboratory, Univ. Minn. St. Paul. 50 pp.

Meyer, M. P. 1979. Personal communication. Dept. Forestry, Univ. of Minnesota. St. Paul, Minnesota.

Meyer. M. P., J. Minor, and L. Werth. 1975. Remote sensing applications in agriculture and forestry: Upper Mississippi River Habitat Inventory quarterly progress report. Remote Sensing Laboratory, Univ. Minn. St. Paul. October. 5 pp.

Minor, J. 1980. Personal communication. U.S. Fish and Wildlife Service. St. Paul, Minnesota.

Mohlenbrock, R. H. 1960. The Cyperaceae of Illinois: I. Cyperus. Amer. Mid. Nat. 63(2): 270-306.

Montanari, J. H. and J. E. Townsend. 1977. Toward a structured ecological data base - the Natural Wetland Inventory and the Habitat Classification and Analysis Group - U.S. Fish and Wildlife Service. In: Proceedings of the 42nd National Wildlife and Natural Resources Conference. 5-9 March 1977.

Moyle, J. B. 1945. Some chemical factors influencing the distribution of aquatic plants in Minnesota. Am. Midl. Nat. 34:402-420.

Moyle, J. B. and N. Hotchkiss. 1945. The aquatic and marsh vegetation of Minnesota and its value to waterfowl. Minn. Fish. Res. Lab., Minn. Dept. Cons. Tech. Bull. 3. 122 pp.

Muenscher, W. C. 1944. Aquatic plants of the United States. Comstock Pub. Co., Ithaca, N.Y. 374 pp.

Nichols, S. A. 1974. Mechanical and habitat manipulation for aquatic plant management. Tech. Bull. 77, Dept. Nat. Resources, Madison, Wis. 34 pp.

Olson, D. P. 1964. The use of aerial photographs in studies of marsh vegetation. Marine Agricultural Experiment Station Bulletin 13, Technical Series. 62 pp.

Organ, J. 1979. Personal communication. Dept. Forestry and Wildlife Management, Univ of Massachusetts. Amherst, Massachusetts.

Paschal, J. 1979. Personal communication. U.S. Geological Survey. Reston, Virginia.

Penfound, W. T. 1956. An outline for ecological life histories of herbaceous vascular hydrophytes. Ecology, 33:123-128.

Phillips, E. A. 1959. Methods of vegetation study. Henry Holt and Co. New York. 107 pp.

Piech, K. R. and J. E. Walker. 1971. Aerial color analyses of water quality. Journal Survey Mapping Division. Proceedings American Society Civil Engineers. SU2(8507): 185-197.

Polcyn, F. C. 1976. Final report on NASA/Cousteau Ocean Bathymetry Experiment - remote bathymetry using high gain LANDSAT data. NASA-CR-ERIM-118500-1-F.

Polcyn, F. C. 1980. Personal communication. Environmental Research Institute of Michigan. Ann Arbor, Michigan.

Polcyn, F. C. and D. R. Lynzenga. 1973. Calculations of water depth from ERTS-MSS data. In: Symposium on Significant Results Obtained From the Earth Resources Technology Satellite -1. 5-9 March 1973. NASA (Goddard Space Flight Center). I (Section B): 1433-1441.

Pollack, H. 1979. Personal communication. Ross Laboratories, Inc. Seattle, Washington.

Prescott, G. W. 1969. How to know the aquatic plants. Pictured key nature series. W. C. Brown, Dubuque, Iowa. 171 pp..

Randall, A. D. and T. L. Marlar. 1978. Coastal zone information from aerial photography. In: Coastal Zone 78 Symposium on Technical, Environmental, Socioeconomic and Regulatory Aspects of Coastal Zone Management. San Francisco, March 14-16, 1978. V. II pp. 1242-1260. ASCE, New York, N.Y.

Raytheon Co. 1974. Technical manual for Model RTT-1000A Portable Survey System. Raytheon Co., Portsmouth, R.I.

Raytheon Co. 1980. Personal communication. Raytheon Co. Portsmouth, R. I.

Robinove, C. J. 1965. Infrared photography and imagery in water resources research. Journal American Water Works Association. 57(7): 834-840.

Rosenshein, J. S., C. R. Goodwin, and A. Jurado. 1977. Bottom configuration and environment of Tampa Bay. Photogrammetric Engr. and Remote Sensing. Vol. 43, No. 6. June 1977. pp 693-699.

Ross, D. S. 1973. Water depth estimation with ERTS-1 imagery. In: Symposium on Significant Results Obtained From the Earth Resources Technology Satellite-1. 5-9 March 1973. NASA (Goddard Space Flight Center). I (Section B): 1423-1432.

Ross Laboratories, Inc. ____. Owner's instruction and service manual for Ross Fine Line Depth Recorders.

Ross Laboratories, Inc. ____. Ross automated survey systems. Technical Bull. No. 555. 17 pp.

Seddon, B. 1972. Aquatic macrophytes as limnological indicators. Freshwater Biology 2:107-130.

Shepard, F. P. 1973. Submarine geology. Harper and Row, New York. 517 pp.

Shima, L. J., R. R. Anderson, and V. P. Carter. 1976. The use of aerial color infrared photography in mapping the vegetation of a fresh-water marsh. Chesapeake Science, V. 17, No. 2. pp. 74-85.

Stewart, R. E. and H. A. Kantrud. 1971. Classification of natural ponds and lakes in the glaciated prairie region. U.S.D.I. Fish and Wildlife Service. Resource Puublications No. 92. 57 pp.

Stockdale, T. M. 1974. Guide to aquatic weed control: What are the problems? Agri-Fieldman Research Bull., Monrovia, Calif. pp. 1-2.

Sverdrup, H. U., M. W. Johnson, and R. H. Fleming. 1946. The oceans. Prentice-Hall, Inc., New York. 1087 pp.

Teleki, P. G. (Chairman). 1973. Remote sensing in oceanography. In: Proceedings of the American Society of Photogrammetry, October 2-5, 1973. Lake Buena Vista, Florida. Part II.

U.S. Army Corps of Engineers. 1969. Revision of master plan for resource management, Pools 11-22, 9-foot Channel Navigation Project. U.S. Army Corps of Engineers, Rock Island District.

U.S. Army Corps of Engineers. 1974. Final environmental impact statement Pool 13 supplement for operations and maintenance, Upper Mississippi River 9-Foot Navigation Channel. USACE. July 1974.

U.S. Army Corps of Engineers. 1978. Upper Mississippi River navigation charts. U.S. Army Engineer Division, North Central Corps of Engineers. Chicago, Illinois. USCOMM-NOAA-DC 1978 R-5655.

U.S. Fish and Wildlife Service. 1976. Existing state and local wetland surveys. Vol. 2. Office of Biological Services. Washington, D.C. 453 pp.

Van Deman, J. 1980. Personal communication. Chicago Aerial Survey. Des Plaines, IL.

Voss, E. G. 1967. A vegetative key to the genera of submersed and floating aquatic vascular plants in Michigan. The Michigan Botanist. Vol. 6:35-50.

Weber, C. I. 1973. Macrophyton. In: Biological field and laboratory methods for measuring the quality of surface waters and effluents. National Environmental Research Center, Office of Research and Development, U.S.E.P.A. Cincinnati, Ohio. EPA670/4-73-00.

Westlake, D. R. 1966. The biomass and productivity of Gylceria maxima. I. Seasonal changes in biomass. J. Ecol. 54: 745-753.

Wezernak, C. T., D. R. Lyzenga, and F. C. Polcyn. 1974. Cladophora distribution in Lake Ontario (IFYGL). Ecological Research Series. EPA-660/3-74-028. December, 1974. U.S. Environmental Protection Agency. Corvallis, Oregon. 77 pp.

Wezernak, C. T. 1975. Distribution of Cladophora. In: Cladophora in the Great Lakes. Great Lakes Advisory Board. pp. 27-49.

Whitlock, C.H. 1980. Personal communication. NASA Langley Research Center. Hampton, Virginia.

Whitlock, C. H., W. G. Witte, and J. W. Usry. 1978. Penetration depth of green wave lengths in turbid waters. Photogrammetric Engr. and Remote Sensing. Vo. 44, No. 11. November 1978. pp. 1405-1410.

Winteringer, G. S. and A. C. Lopinot. 1966. Aquatic plants of Illinois. Dept. of Registration and Education, Illinois State Museum and Department of Conservation, Division of Fisheries. Springfield, Ill. 141 pp.

Wisconsin Department of Natural Resources. 1975. Inventory of coastal imagery - a continuing report.

Wood, R. D. 1975. Hydrobotanical methods. University Park Press. Baltimore, Ohio. 173 pp.

Yost, E. F. and S. Wenderroth. 1968. Coastal water penetration using multi-spectral photographic techniques. Proc. 5th Symp. Remote Sensing of Environment. Univ. of Michigan, Ann Arbor. pp. 571-586.